DOCUMENT RESUME

ED 389 524 SE 056 804

AUTHOR	Berlin, Donna F., Comp.
TITLE	SSMILES: School Science and Mathematics Integrated Lessons.
INSTITUTION	National Center for Science Teaching and Learning, Columbus, OH.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, D.C.
PUB DATE	[95]
CONTRACT	R117Q00062
NOTE	169p.; A few pages contain light, broken type.
AVAILABLE FROM	NCSTL, 1929 Kenny Road, Columbus, OH 43210-1080.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Class Activities; Elementary Secondary Education; Hands on Science; *Integrated Curriculum; Lesson Plans; Mathematical Concepts; *Mathematics Instruction; *Science Instruction; Scientific Concepts

ABSTRACT

This document is a compilation of lesson plans designed to teach math/science concepts that have appeared in the journal "School Science and Mathematics". The activities combine important mathematics and science fundamentals in a single lesson and have been tested by classroom teachers. The lesson plans include concepts, objectives, rationale, lesson outline, procedure, evaluation, teacher notes, extensions, references, and relevant activity sheets. The units involve hands-on activities that use readily available, everyday materials. (JRH)

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ED 389 524

School Science and Mathematics Association

SSMILES

SCHOOL SCIENCE AND MATHEMATICS

INTEGRATED LESSONS

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This publication was supported by the National Center for Science Teaching and Learning under grant #R117Q00062 from the Office of Educational Research and Improvement, U.S. Department of Education. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the sponsoring agency.

Capture Recapture: Sampling with Replacement

Grades 5-7

	Mathematics Content	*Science Content*
Concept:	ratio, proportion	population
Skill:	table making	sampling, recording
Process:		inference, estimation

Prerequisite skills: counting, classifying/sorting, multiplication, fractions.

Objective: The student will estimate population size using proportion in a hands-on activity.

Rationale:

Content Background: Capture and recapture is a sampling tool used in the life sciences to estimate population sizes in a given area. A researcher might use this technique to determine the number of salamanders on a hillside. The scientist would capture a group of salamanders, mark them, release them and recapture them. The total population size would be estimated from the proportion of marked salamanders to unmarked salamanders in the recaptured sample. Proportion is a mathematics skill that is applied to many real world situations. This example from the life sciences requires that students be able to determine a missing term to form a proportion.

$$\text{(from sample)} \quad \frac{\text{``tagged animals''}}{\text{untagged animals}} = \frac{\text{total in sample}}{X} \quad \text{(estimate)}$$

(X is the estimation of the total population)

Instructional model for activity: This activity uses concrete materials to demonstrate integrated process skills. The student is an active participant in data collection, analysis and application/extension.

Lesson outline:

Time: 45 minutes

Materials/supplies (per group): dried pinto beans (1 oz.), dried kidney beans (4 oz.), one plastic container (about 8 oz. cool whip size)

Preparation: Before class fill containers half full of kidney beans.

Procedure:

1. Introduce the concept of sampling. Provide an example from the life sciences (bird banding, salamanders). Capitalize on local interest.
2. Divide the students into groups of 4. Assign the responsibilities of counter, recorder, sampler, and reporter.
3. Students estimate the number of kidney beans in the container. Record prediction on the worksheet.
4. Student sampler in each group will remove one handful of kidney beans.
5. Count the kidney beans. Record actual number of beans. Teacher collects these beans.
6. Replace kidney beans with the same number of pinto beans.
7. Sample by removing another handful of beans. Count the number of pinto beans and kidney beans removed. Record these numbers in the table. Add them together for the total.
8. Replace the beans in the container.
9. Estimate total population size of kidney beans based on sample of mixed beans. Record the estimate on the worksheet.
10. Repeat steps 7, 8 and 9 five more times.
11. Each reporter will share the estimations of the group and method of determining population size.
12. Note to teacher: If no group using proportion as an explanation of their estimation, give another example of the math skill for proportion used in life sciences.

$$\frac{\begin{array}{c}\text{number of pinto beans}\\ \text{in one handful}\end{array}}{\begin{array}{c}\text{number of kidney beans}\\ \text{in one handful}\end{array}} = \frac{\begin{array}{c}\text{total number of beans}\\ \text{in one handful}\end{array}}{\begin{array}{c}\text{total number of beans}\\ \text{in the container}\end{array}}$$

13. Repeat procedure 7, 8, and 9 so that all groups can use the proportion technique to estimate the population size.

14. Count all beans in the container and record.

15. Compare the initial estimate of total beans and the estimates from step 8 with the actual number of beans.

16. Relate this activity to real world, life science examples.

Teacher Notes:

Extension:

1. Construct a graph with the estimated population sizes from step 8 on the vertical axis and the actual sample size on the horizontal axis. This will show if the successive estimates from step 8 approached the actual number of beans.

References:

"One If By Air . . . Two If By Sea," *The Challenge of the Unknown*. New York: W. W. Norton & Company, Inc., 1986. (Developed through a grant by the Phillip Petroleum Company).

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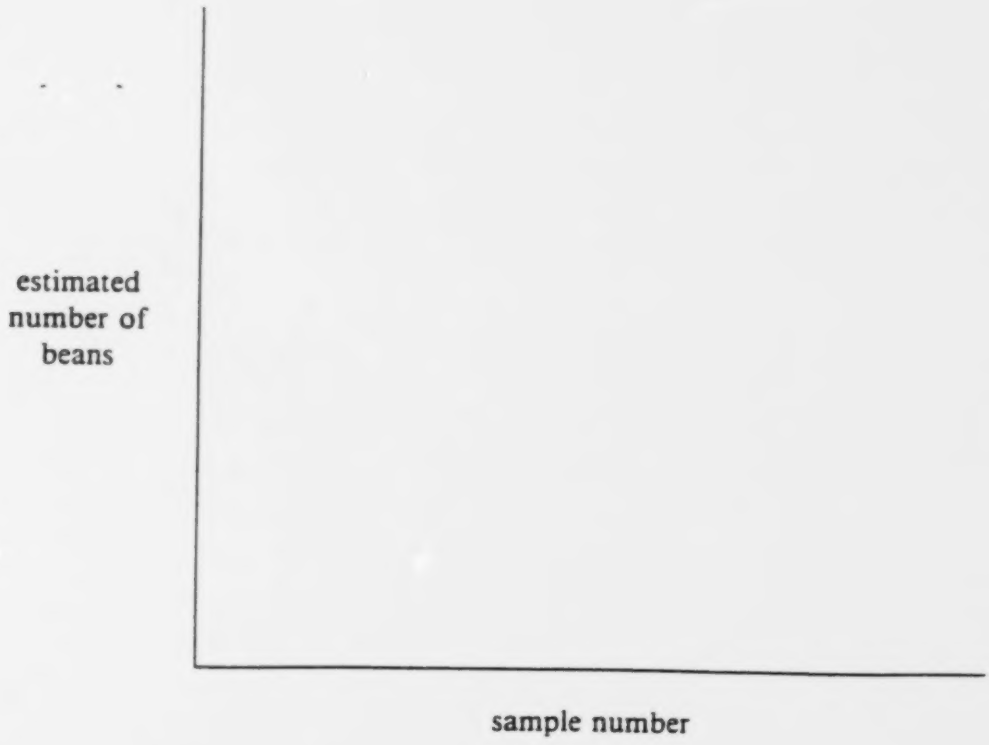
Handouts: Student Worksheet

How many kidney beans are in the container?____________________________

How many kidney beans are in your first handful?________________________

sample number	number of kidney beans in one handful	number of pinto beans in one handful	total number of beans in one handful	estimate of total beans in container
1.				
2.				
3.				
4.				
5.				
6.				

Extension Graph:



Draw a horizontal line showing the actual number of beans in the container. How close were your estimates to the actual number?

SSMILES

How Well Hidden
Modeling Natural Selection
Grades 5-9

Mathematics Concepts/Skills

percent, ratio, proportion,
calculator skills,
table construction,
and prediction.

Science Concepts/Processes

natural selection
data collection
modeling, hypothesizing,
controlling variables

Prerequisite skills:

counting, classifying/sorting, multiplication

Objective:

The student will develop a model of natural selection and then use it to construct tables from which to make predictions about the "survival" of various colored organisms.

Rationale:

Content background: Natural selection is the process of interaction between an organism and its environment resulting in differential survival and reproduction rates among organisms within a population. Eventually this selection pressure can result in changes in the gene pool for that population. A common example of natural selection is the change in frequency of the light and dark peppered moth with the onset of the industrial revolution.

Natural selection takes too much time to observe in a classroom situation, so we will model it. Models are used to represent phenomena that happen too quickly or too slowly to observe or that are too small or too large to observe. Commonly, we use models to represent chemical reactions, DNA molecules and for city planning. Our model of natural selection uses printed fabrics to represent the environment and colored dots to represent a variety of organisms.

The students measure the pattern on the fabric, calculate the area of various colors, form ratios and proportions, and predict which organisms will be most likely to "survive." Many mathematical concepts are reviewed and then applied. Percents are utilized as they provide a common index which facilitates comparisons and prediction.

Instructional Model For the Activity: This activity reviews many lower level process skills and then builds upon them to use ratio and proportion in a situation requiring prediction and modeling. This activity uses concrete materials to represent the factors influencing natural selection, an abstract concept. Our problem is to observe natural selection, our strategy is to develop a model and our tools are mathematics skills.

Lesson Outline:

Time: 45 minutes without extension activities

Materials/Supplies per group:

One piece of fabric the size of a table top (30" x 48") with a red and white geometric pattern (any regular pattern that lends itself to area calculation will work) five vials each with at least 100 dots of red, white, navy, black and orange paper, ruler, and calculator. Hint: use a paper punch to make the dots.

Preparation: prepare vials with colored dots, push desks together or clear a floor area to give a larger work area.

Procedure:

1. Introduce natural selection and give some examples of cryptic coloration and mimicry. The dark and light forms of the British peppered moth, the stripes of a tiger and the spots of a fawn are examples of cryptic coloration. The viceroy butterfly reaps the benefits of the distasteful monarch it mimics in coloration. Inquire as to how we might observe the process of natural selection.

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2. Brainstorm with the class and weave into the discussion examples of models used in other situations. We model DNA because it is too small to be seen, chemical reactions because they happen too quickly to be observed, and natural selection because it is too slow to be conveniently observed. Lead the class to propose a model as the solution to the problem of being unable to observe natural selection in nature.

3. Divide the students into groups of 4.

4. Each group chooses a cloth to use as an "environment" and spreads it smoothly on the work area.

5. Each group takes 20 dots of each color (100 dots total) and spreads them evenly over the cloth being careful not to lose any as accuracy is important.

6. Each student looks away from the cloth, then back at it and removes the first dot he or she sees as would a predator when taking an organism. Remove only one dot at a time. Continue this process until 75 dots have been removed. (Hint: if the students quietly count each dot as they remove it, they will know when they have reached 75.

7. Sort and count the remaining 25 dots. For each of the remaining 25 dots, add 3 more dots of the same color. The total will once again be 100 dots. Now record the number and percent of each color on Data Table 1. Stress that percent is best explained as a ratio with a denominator of 100. The 100 dots adapt very well to this activity, e.g. if 14 of the remaining dots are red, the ratio would be 14/100 and the percent would be 14.

8. To begin a "new generation:" Mix the dots and distribute them on the cloth. Repeat steps 6, 7 and 8 until there is little change in the percent of colors remaining on the cloth.

9. Discuss your results in terms of "survival of the fittest." Why would you expect certain colors to remain? Were you surprised at which colors were first selected? How could we predict which colors and how many of each color will remain?

10. Predicting which colors will remain necessitates that the students determine the area of each of the colors in the fabric. In order to predict how many of each color will remain, students must calculate the percent of the total area that is covered by that specific color. If for example the cloth has equal area of red and white, little difficulty will result in determining the area, i.e., 50% red and 50% white. If there are more colors or if the colors are not equal, some system will need to be used to calculate or estimate. If regular shaped areas such as stripes, squares, circles, triangles, etc. are used, area calculations can be used. A method of estimating irregular areas is later included under "extension."

11. First calculate the total area of the fabric before calculating the area of the two colors. Form a proportion: Area of red/Total area = N/100. Through the process of cross multiplication we can determine N, which is the percent of area that is red. Use Data Table 2 to record your data and to make calculations.

12. Now, repeat steps 6, 7, and 8. How did your predictions compare with the actual number and color of dots remaining on the fabric?

Evaluation:

Evaluation could take the form of class discussion. To help determine if the students understand the concepts of natural selection and modeling, ask them if their particular cloth and dots could represent a real world situation.

Teacher notes:

Extension: There are many extensions appropriate for different grade levels.

1. Take the activity outdoors and use hula hoops to define an area and colored toothpicks, jelly beans or Indian corn for "organisms."

2. Use calico or flowered cloths to more closely represent the natural environment. Hypothesize changes in survival resulting from seasonal changes or catastrophic events. The students will need to utilize a process of

DATA TABLE 1

GENERATION	NUMBER OF DOTS REMAINING IN STEPS 7 AND 8.									
	Color #1 (red)		Color #2 (navy)		Color #3 (black)		Color #4 (orange)		Color #5 (white)	
	N	%	N	%	N	%	N	%	N	%
1										
2										
3										
4										
.										
.										

DATA TABLE 2

COLOR OF PATTERN	% OF TOTAL AREA	PREDICTING REMAINING DOTS	
		COLOR	NUMBER

determining areas of both regular and irregular patterns. If irregular shapes are in the fabric, a transparency of square grids may be laid over the fabric and estimation used to closely approximate the various areas.

References:

Use any introductory biology book for examples and background information. Look up natural selection, cryptic coloration, and mimicry in the index.

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Following discussion at the School Science and Mathematics Association Middle School Task Force meeting in Lexington, KY.

Handouts: Student worksheets

FAMILY PLANNING
Grades 6-8

Mathematics Concepts/Skills
mean, random, ratio use of random table, computer skills, and prediction.

Science Concepts/Processes
population control, data collection and organization, simulation, and inference.

Prerequisite skills: counting, adding, dividing.

Objective: Using simulation, the student will estimate the average size of a family in a community that uses a given method to plan the family.

Rationale: Simulating a phenomenom to predict its outcome is a process widely used when direct observation or experimentation is too expensive or infeasible. Coins, random tables, and computers can be used in school to simulate experiments.

Lesson Outline:

Materials: coin, random table or computer, student handouts.

Procedure:

Introduction
The community of Cihuatlan is patterned after a matriarchal system. It is therefore very important for a family to have a female descendant. The community has recently experienced a huge population growth due mainly to reduction in infant mortality and better life conditions in general. The community is concerned with the population explosion and has developed the following system to plan a family: each couple will have children until they have a girl. After that, they will not have any more children. However, before implementing the system, they want to know what consequences it will have with respect to population growth, rate of males to females, average size of a family.

Student activity

1) Coin simulation
Simulate Cihuatlan's Family Planning System with a coin. Flip a coin until you get heads. Write T if you get tails, H if you get heads. Write the total number of times you have to flip the coin until you get heads.

Example:

Outcomes	Total
T T H	3
T H	2
T T T H	4
H	1

Write down the outcome of one experiment

Outcome ________ Total ____

2) Use the random table to simulate the Family Planning System with ten couples.
This table has printed B or G in a random order. To use the table, close your eyes and pick a letter of the table. Circle that letter. From that place on, take the letters to the right in the order they appear on the table until you get a G. Begin another sequence of letters until you get a G. If you come to the end of a line continue with the line below. Repeat the experiment ten times.
Example: Suppose that on the line picked, letters appear in this order.

BGBBB GGBBB GBBBB GBGGB GBBGB GBGGB BGGBB

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The outcomes would be written in the following way:

BG	2
BBBG	4
G	1
BBBG	4
BBBBG	5
BG	2
G	1
BG	2
BBG	3
BG	2
	Average: 2.6

Now write down the outcomes of your simulations and the total number of letters until you get a G. Take the average.

Outcomes	Total
________	____
________	____
________	____
________	____
________	____
________	____
________	____
________	____
________	____
________	____
	Average:

Write down the averages of ten of your classmates:

____
____
____
____
____
____
____
____
____
____

Take the average of the averages: _____
This average represents the average of 100 simulations.
This average is an estimation for the number of children that a couple in Cihuatlan can expect to have if they follow the Planning System.

What is the expected value for the number of children per family? _____
How many boys and how many girls will there be? _____
What would the ratio of boys to girls be? _____
How fast would the population in Cihuatlan grow? _____

3) The random table was generated by a computer. You can also use a computer program to simulate the Planning System.

```
10 REM FAMILY PLANNING APPLE VERSION
20 FOR N = 1 TO 20
30 LET T = 1
40 IF RND(1) <0.5 THEN GOTO 80
50 PRINT "B ";
60 LET T = T + 1
70 GOTO 40
80 PRINT "G", T
90 NEXT N
100 END
```

Run the program to see simulations for 20 couples. Run the program several times. The program can be easily modified to see more experiments, and take the average.

Conclusions

A coin, a random table, or a computer can be used to simulate phenomena. In the case or Cihuatlan's Family Planning System we can take the results of many simulations to predict what would happen in the community if the plan was adopted.

If all couples in Cihuatlan follow the plan, the expected value for the number of children per couple is 2, and since there is always a girl, the ratio of boys to girls would be 1 to 1. According to this plan, Cihuatlan would have zero population growth.

Teacher Notes:

It is very instructional to flip the coins. Let all students simulate the Planning System with the coin at least once. Write down the results on the blackboard and discuss the outcomes.

The advantage of using the random table or the computer is of course that many more simulations can be done in less time and a more precise prediction made.

Extensions:

Students can also look at and graph the distribution of the outcomes. For example, about one half of the families would have only one child (Why?). About 1/4 would have two children, about 1/8 would have three, and so on.

References:

Flores Peñafiel, Alfinio; Lerma Rico, Jovita; Mártinez Cruz, Armando; Mirabal García, Francisco. (1987). *Prácticas de matemáticas para segundo de secundaria.* Comunicaciones del CIMAT, Guanajuato, MEXICO.

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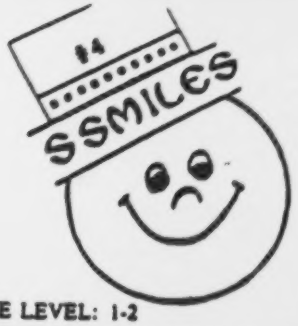
RANDOM TABLE

BGBGB BGGBG BBGGG GGGGB BBGGB	GBBBB BBBGB GGGGB GGGBB GBGBB	GBGGB BGGBG GGBBB GBGGG GBGGG	BGBBG BBBGG BGBGB GBGGB GGGGB	BGGGB BBGGG BGBGG GBGBB GGBBB
BBGBB BGGGG GBGGB GBGBG BBBBG	GBGGG BGBGB BBBBG GGGBB BBGGG	BGBBB GBBGB BGBGB BBGBG GGBBB	BBBGB BGBBG BBGGG BGGBB GBBBG	BGBBB BGGBB GGBGG BBGBB BGGGG
GGBGB GBBBB GBBGB GBGGG BBBGB	GGGGG BGBBG BGGBB BBGGG BGBBG	GBGBB GBGBB BGBGB GBGGB BBBBB	GGGGB BBBBG BBBGG GBBGG GGBBG	BBGBG GBBGB BBBBG BGBGG GGGGB
BGGBB BBGGB GGBBB GGGBG GGGGG	GBBBB GGBBG BBGGB GGGBB BBGGB	BBGBB BGGBG BGGGB GGGGG BGGBB	BBGBB GGBGB BBBGB GBGGG GGBGG	GGGGG GGGGG BGBBB BBGBB GBBBG
BGGBB GGGGB GGGGB GGBBG GBGBG	GGGBB GGGGB GGBGB BGBBG BGBGG	GGGGG BBGGB BBBBG GGGBG GGGGB	GBGBB BBBBG GBBGG BBGBG GBGGB	GGGBG BGGGB GBBGG GGBGB GBBGG
BBGGG BBGGB GGBBB BBBBG BGBGG	BBBGG GGBBB BGBGG GBGBB BGBGB	BGBBG GBGGB BBBBB BGBBG GBGBG	GGGBG BGBBG BGBGG BBBGB GBBGB	GGBGG GGBGG GBGBG BBGBG BGGBG
GBBBG GGBGG GBBBG GBGBB BBBGB	GBGGB BGBBG GBGGG BGGBB BGBGB	GBBBG BGBGG GBGGG GGBGG BBGGB	GGGGG GBGGB BBBGG BBBBG GBBBB	BGBBG BBGBB BBGGG GGGGG BBGGB
GBBBG GBBGB BBBBB BGGGG GBBBG	GGGGB GBBBB GGGGG BBGGG GBBBB	BBGGB GGBBG BGGBB BGBGG BGBGB	BGGGG BGBGB BBBBB BBGBB GBGBG	BGBGB GGBBG GBBGB BBGGG BBGGB
GBGBB BGGBG BGGGB BGBBG BBGGG	GGGBG BGBGG GBGGG BBBGB BGGGG	BGGGG GGGGB GBGBB GGGGG BBGGB	GGBBB GGBBB BGBGB GBBGG GBGBB	GBGGG BGGBB BBGBB BGGGB GGGGB



A TRIP TO THE ZOO—A LESSON IN GRAPHING

GRADE LEVEL: 1-2

MATHEMATICS AND SCIENCE CONCEPTS:

1. Classification of animals
2. Gathering data on types of animals
3. Construction of pictographs and bar graphs
4. Interpretation of graphs
5. Vocabulary development appropriate to graphing skills

PREREQUISITE SKILLS:

1. Knowledge of linear measurement
2. Knowledge of whole number concepts
3. Knowledge of simple classification of animals
4. Knowledge of the concept of graphing

OBJECTIVES:

1. Development of classification process
2. Gather data and prepare information in graph form
3. Understanding of concepts of more, less, same

RATIONALE: The lesson will

1. Help students learn types of animals in the zoo
2. Teach students to gather and organize data
3. Teach students to display data in graph form
4. Develop vocabulary used in graphing
5. Help students move from concrete to abstract thinking

LESSON OUTLINE:

MATERIALS NEEDED: Pictograph and bar graph worksheets (samples provided may be changed as needed), ribbons for bar graph, stickers or pictures for pictographs

Make arrangements for a field trip to a zoo.

Prior to the field trip:

1. Discuss different animals found at the zoo
2. Review other graphing experiences students have had
3. Discuss information to be collected by the students
4. Discuss ways of collecting and recording information
5. Show students pictographs and bar graphs as examples of the graphs to be constructed upon returning to school.

During the field trip:

1. Review information to be collected, how to collect it and how to record it.
2. Continuously monitor students' progress in data collecting

After the field trip:

1. Review information collected by students
2. Distribute pictograph and bar graph worksheets
3. Students construct pictographs using stickers or pictures and bar graphs using ribbons.
4. Discuss information on the individual graphs, comparing results with each student.

EVALUATION: Observe each student's graphs for accuracy. Evaluate the student's ability to describe information the graph contains.

School Science and Mathematics
Volume 87 (7) November 1987

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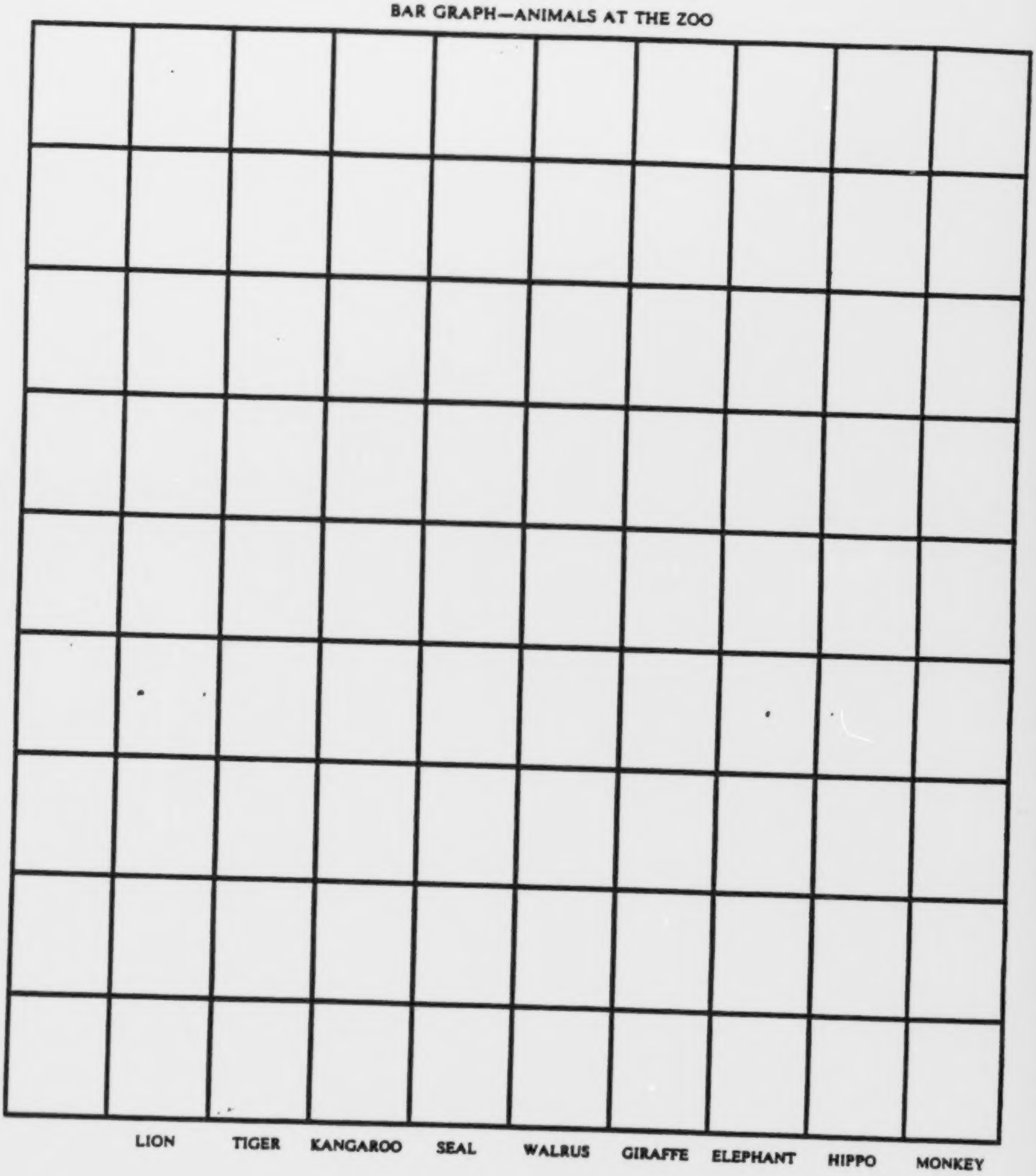
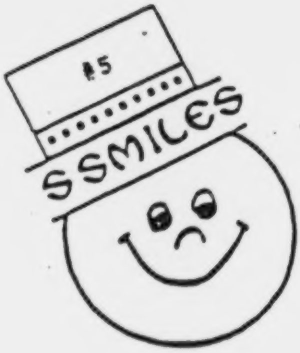
BAR GRAPH—ANIMALS AT THE ZOO



Pictograph—Each picture = one animal

TIGER	RACCOON	SKUNK	FOX	LEOPARD	PANDA



Sampling and Inference
Grades 5 - 9

Mathematics
Concepts/ Skills
area of a circle
absolute value
sampling
part-whole relations
ratio and proportion

Science
Concepts/ Processes
estimation/ inference
experimental error
measurement error
sampling error
percent error

Prerequisite Skills: Ability to compute the area of a circle, averages, part-whole relationships, and absolute values.

Prerequisite Activities: The student should be given instruction and practice in using a calculator for computing averages and simple exponent operations:

A. the average or mean of a series of ten or more numbers.

B. the area of a circle using the formula:

Area = pi × r^2
where pi = 3.14 and r = radius of the circle.

C. exercises in expressing the absolute value of positive and negative numbers and the absolute value of the difference between two numbers for which the difference can be positive or negative.

Objective: The student will conduct and validate a sampling procedure and determine the percent of error in it's application.

Rationale: In scientific research, scientists are trying to gain knowledge about a large class of objects, persons, or events (population) from a relatively small class of the same type of elements (sample). Scientists study the properties of small samples in order to make inferences about the properties and characteristics of the population. For instance, the number of stars in the sky are too many to count but if we can count the number in a small area of the sky we can then make an educated "guess" as to the total number. If we compare the small area of the sky for which we count the stars to the total area of the sky we can improve our "guess". These "guesses" are called ESTIMATES and the process for making these "guesses" is INFERENCE.

Like all "guesses" some are better than others and errors occur from time to time. It is important to know something about how much error might be expected in an INFERENCE. This error is expressed in many ways. One way is to relate how different your "guess" is from the actual or theoretical value. This method of error representation is most often presented as a percentage. Some of this error will be due to the experimental procedures for gathering the data (experimental error); some will be due to the precision of the measurement instrumentation (measurement error); and some will be due to the samples you happen to select from the population (sampling error).

Lesson Outline:

Time: 30 to 50 minutes

Materials/ Supplies per class:

1 poster board at least one meter by one meter with a 50cm radius circle drawn with a broad tip black marker.

675 red dot stickers, 2 - 5mm radius, placed within the 50cm radius circle in a random fashion.

1 note card at least one decimeter by one decimeter with a 5cm radius circle drawn on it with a broad tip black marker.

Materials/ Supplies per student:

1 tube measuring 1.5 inches (3.81cm) or less inside diameter and 11 inches (27.94cm) or more in length. The tube inside of a standard roll of paper towels has an inside diameter of 1.5 inches and is 11 inches long.

Procedure:

1. About 2 - 3 weeks before the activity tell the students that they will need to bring one or more cardboard tube(s).

2. Hang the 50cm radius circle with the red circle stickers on the wall or chalkboard.

3. Tape the 5cm radius circle (sample) on the same surface as the large circle (population).

4. Each student should calibrate their viewing tube by viewing the sample circle through their tube and find the distance for which the field of view and the sample circle coincide.

5. Each student should then move the viewing tube around without changing the distance from the large circle. This should be done in a "random" fashion stopping from time to time to count the number of red dots in view.

6. Each student should repeat this procedure until 10 samples are counted. Each sample count should be recorded as it is made with the sample # and the number of red dots for each sample on a data table (see the accompanying handout).

7. Average the number of red dots counted over the 10 samples (see Teacher Note 1).

8. The average number of dots viewed through the tube should be multiplied by 100 to get an estimate of the total number of red dots on the poster (see Teacher Note 2).

9. Have the students count the number of red dots within the large circle and compare their estimate to the actual number.

10. Determine the average percent error for the entire class. The percent of error can be calculated as follows:

100 × ABS (actual # − estimated #/actual #
e.g. 100 × ABS(456 - 500)/456 = 100 × 44/456
100 × 0.0965 = 9.65% error

Evaluation:

1. The student should be able to describe a procedure they would use to estimate the number of dandelions on the high school football practice field.
2. The students should be able to compute the average number of zebra sighted during 25 separate safari trips on the Masai Mara in Kenya, East Africa.
3. The students should be able to calculate (using a calculator if they wish) the percent of error of a sampling procedure if they are given the actual and estimated values.

Teacher Notes:

1. It is recommended that a calculator be used during this process and for all other computations so that the students can focus on the sampling concepts and not get bogged down with the computations.

2. The field of view through the paper towel tubes can be varied as needed. In this procedure, when the student views the field of red dots with an 11 inch tube of 1.5 inches in diameter from a distance of 18.5 inches from the plane of the large circle, the field of view is a circle with a radius of 5cm.

Since the large circle has a radius of 50cm it's area can be found from the following formula:

Area = pi × r^2 or

A = 3.14 × $50cm^2$ = $7850cm^2$

Since the small circle which represents the field of view of the cylinder, has a radius of 5cm it's area can be found from the following formula:

Area = pi × r^2 or

A = 3.14 × $5cm^2$ = $78.5cm^2$

Each sample represents $78.5cm^2$ which is 1/100 of the area of the big circle. Therefore, the average number of red dots for the 5cm circle must be multiplied by 100 to get the estimate of the number of red dots in the 50cm circle. Since the total area of a circle is a function of the square of the radius, the ratio of the radius of the sample circle (5cm) and the radius of the population circle (50cm) can be determined (500cm/5cm = 10) and then squared (10^2 = 100) to determine the multiplier.

The field of view is related to 4 factors which can be manipulated by the students. These factors are:

A. The distance of the tube from the viewing surface,
B. The radius of the viewing tube,
C. The length of the viewing tube, and
D. The distance of the viewer's eye from the viewing tube.

It is recommended that the last factor be held constant by requiring that the tubes be held as close as possible to the eye during data collection. If the sample circle is kept constant with a 5cm radius, then the distance from the large circle can vary depending upon the length and diameter of the viewing tube. For instance, if a viewing tube with a radius of 3.5mm and a length of 12.7cm is used, the observer will have to make observations from a distance of 120 - 150cm in order to have a field of view with a 5cm radius. It is convenient to keep the ratio of the area of the sample viewing circle and the area of the population circle at 1 to 100 but this is not a necessity.

References:

Glass, G. V., & Stanley, J. C. (1970). *Statistical methods in education and psychology*. New Jersey: Prentice Hall, Inc.

Hynes, M., Douglass, C., & Jones, S. (1987, April). SSMILES: Capture recapture: Sampling with replacement, *School Science and Mathematics, 87*(4).

O'Brien, G., & O'Farrell, C. A. (1988, January). SSMILES: A method to count the number of stars in our galaxy, *School Science and Mathematics, 88* (1).

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Handout:

DATA TABLE

Sample #	Number of red dots
01	
02	
03	
04	
05	
06	
07	
08	
09	
10	

________ / 10 = ________ × 100 = ________

ESTIMATED NUMBER OF RED DOTS

Absolute Value of Difference

(________ – ________) = ________ (omit sign)

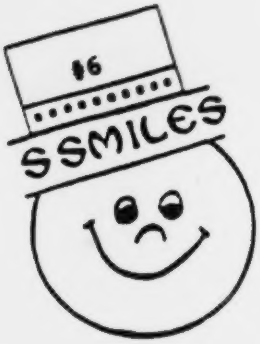
ACTUAL # OF RED DOTS (counted)	ESTIMATED NUMBER OF RED DOTS	ABSOLUTE ERROR OF ESTIMATE

________ / ________ = ________

ABSOLUTE ERROR OF ESTIMATE	ACTUAL # OF RED DOTS	PROPORTION OF ERROR IN SAMPLING PROCEDURE

________ × 100 = ________ %

PROPORTION OF ERROR IN SAMPLING PROCEDURE	PERCENT OF ERROR IN SAMPLING PROCEDURE



Sampling: A Method to Count the Number of Stars in Our Galaxy

Grades 5-9

Mathematics Concepts/Skills
Area, ratio, proportion,
table construction,
sampling, prediction

Science Concepts/Processes
Astronomy,
data collection, recording,
estimation, inference

Prerequisite Skills:
counting, classifying/sorting, averaging, fractions

Prerequisite Activity:
"SSMiles: Sampling and Inference" (White and Berlin, 1987), a classroom simulation of the stars and the use of the sampling method to estimate their number

Objective:
The student will estimate by sampling method the number of stars in a portion of the Milky Way Galaxy

Rationale:
Content Background: Scientists and mathematicians encounter problems where the counting of a very large number of elements is necessary. An important method for obtaining estimates of numbers is known as sampling. Sampling is a method used by scientists to estimate the total amount by finding the average from a number of small samples. An excellent opportunity to introduce the concept of sampling exists when studying astronomy. All the stars that you can see without a telescope are in the Milky Way Galaxy. The Milky Way Galaxy is a very large group of stars rotating around a center. Astronomers say there may be one hundred billion stars in our galaxy.

Instructional model for activity: This activity uses concrete materials to demonstrate integrated process skills. The student is an active participant in data collection, analysis and application/extension.

Lesson Outline:
Time: 50 minutes without extension activities

Materials/Supplies per student: Paper tube 11 inches by 1.5 inches in diameter, pencil

Preparation: Have students prepare paper tubes. Observe weather forecasts and assign the activity when a clear night sky is predicted.

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Procedure:

1. Introduce the activity by asking the question: How many stars can you see on a clear night? Focus the discussion on different techniques or strategies one could use to answer the question. Let the students by reasoning infer difficulties in a direct count procedure.

2. Review the "SSMILES: Sampling and Inference" activity, and discuss how similar methods might be employed to estimate the number of stars in the Milky Way Galaxy.

3. Make the paper tubes and assign the activity.

4. Each student looks through the tube at a part of the night sky.

5. Count the number of stars you see in that part of the sky. (Count it 0 when you can't see any stars.)

6. Use Data Table 1 to record your data. Write down the number of stars in Sample Number 1.

7. Follow several paths across the sky. Stop at several places at random.

8. Count and record the stars you see in the tube each time you stop.

9. Do this 25 times. Why is it important that you take at least 25 samples?

10. Complete the following calculations on Student Worksheet 1. Add all the stars you counted in the samples and divide the total by the number of samples you took. Be sure to include those samples in which you recorded no stars. This number is the average number of stars for each sample part of the sky.

11. Astronomers have calculated that about 700 samples would cover the entire sky, so multiply your average number per sample by 700. This gives you approximately the number of stars you can see in your sky.

12. During class the following day, place the students' final calculations on the chalkboard or overhead projector. Have students compare and discuss the findings. Why are there different results?

13. What techniques might astronomers use in order to get better approximations of the number of stars in our galaxy?

Evaluation:

Evaluation could take the form of classroom discussion. Key concepts and operations include: (1) students use the method of sampling to obtain estimations; (2) Students apply the sampling method to a natural setting; and (3) students become aware of the large number of stars in our galaxy.

Teacher Notes:

Alternative approaches or extension activities to investigate the same concepts as in this activity include:

1. If the class has access to a planetarium, the paper tube technique can be utilized as an in-class investigation.
2. If the class has access to a camera and telescope apparatus, then a photographic technique similar to that used by astronomers might be attempted.
3. Prepared photographs with known area dimensions of the night sky might be employed with sampling procedures.

References:

Brandwein, P. F., Cooper, E. K., Blackwood, P. E., and Hone, E. B. (1966). *Concepts in Science* (pp. 380-386). New York: Harcourt, Brace and World, Inc.

White, A. L., and Berlin, D. F. (1987, December). SSMILES: (Sampling and inference, *School Science and Mathematics, 87*(8).

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SSMILES

Handouts: Student worksheets

DATA TABLE 1

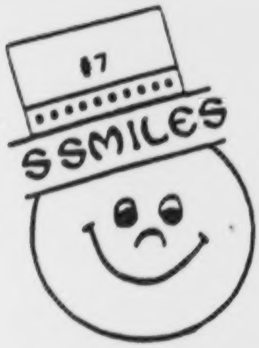
Sample Numbers	*Total*
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

Total of Samples =

STUDENT WORKSHEET 1

$\frac{\textit{Total of Samples}}{25}$ = ____________ average number of stars per sample

Average number of stars per sample × 700 = number of stars in sky ________________ × 700 = ________________



This Group . . . That Group
Sorting Leaves and Making Patterns
Preschool/Kindergarten

CONCEPTS, SKILLS, PROCESSES

Mathematics	Science
sorting	dichotomous keying
comparing	observing
patterning	describing

Prerequisite skills: none

Objective: The student will describe leaves and sort them according to dichotomous characteristics. They will then create patterns based on those characteristics.

Rationale:

Content background: Accurately describing the characteristics of organisms is a fundamental process skill for all sciences. Students hone their observational and descriptive skills through practice and this activity provides such practice. Most taxonomic keys are based upon a series of dichotomous characteristics. Sorting into subsets according to these characteristics is an important premathematics skill. Developing patterns based on subset characteristics is a basic mathematics readiness skill. By integrating these mathematics and science processes, young children develop mathematics and science skills through concrete experiences.

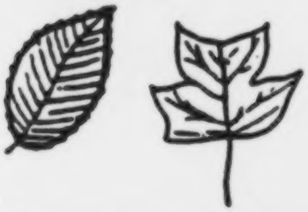
Instructional model for activity: Processes are heirarchial. Observation, description and classifying/sorting are prerequisite to all higher level processes necessary for advanced science and mathematics. This activity provides appropriate, hands-on practice of these lower level processes.

Lesson outline:

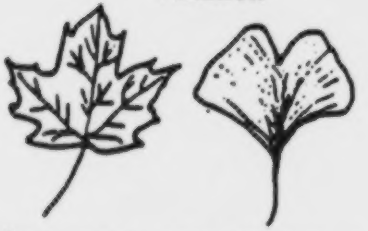
Time: 10-20 minutes each day for a 2 week period.

Materials/supplies: Leaf identification chart or books. Collection of leaves showing a variety of dichotomous characteristics. For example, these leaves show differences in leaf edge and venation.

Leaf Edge



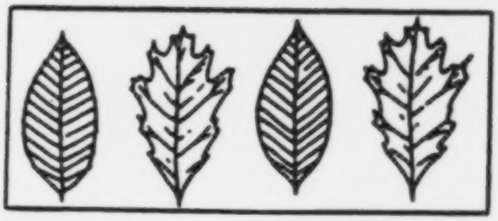
Venation

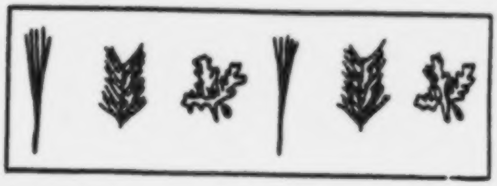


Preparation: Students or teacher collect, press and, if desired, laminate leaves. The teacher could construct a worksheet or picture key which would allow the student to identify the leaf (see Appendix for example). To simplify the identification, include only those species common to your students' leaf collection in the key.

Procedure: This activity may be set up in a learning center for individual use or it may be done by the entire class.

1. Students should have time for free play and "hands-on" time with the leaves before the directed activity. (Children will begin to spontaneously sort and classify the leaves).
2. Encourage the students to carefully observe the leaves. They should note the color, size, leaf edge (margin), the pattern of growth, and the vein pattern (venation).
3. Ask students to choose a specific leaf and to describe it as completely as possible.
4. Direct the sorting experience based on the characteristics in step 2 and 3.
5. Present simple patterns based on a single characteristic for the students to duplicate. For example, green leaves alternating with yellow leaves, or lobed leaves (oak) alternating with toothed leaves (beech). If the activity is in a learning center, task cards could be used.
6. Ask students to continue the patterns of step 5 beyond your example or the task card. This requires them to recognize the pattern and extend it rather than merely to visually match the items on the task card.





7. Have the students create their own patterns based upon a single characteristic.

8. Repeat steps 5-7 using a variety of characteristics.

Evaluation: Evaluation is done through informal observation of the student's performance of each step in the procedure.

Teacher Notes:

Extensions:

1. Do this activity entirely using herbs and sort by smell, blindfolded (do not laminate these leaves).
2. The textural characteristics can be easily identified by the visually impaired student (do not laminate, but press well).
3. Make a simple picture key and have the students use it to name the leaves.
4. Go on a scavenger hunt to find leaves with specific characteristics identified in this activity.
5. There are many art extensions including leaf rubbings, repeated and more complex designs, and "stained glass" window patterns using leaves and wax paper.

References:

Brockman, C. Frank. Trees of North America. 1968. New York: Golden Press.

Rockwell, Robert E, Elisabeth Sherwood, and Robert Williams. Hug a Tree, 1983. Gryphon Press, Mt. Ranier, Maryland 20712.

Watts, May Theilgaard. Master Tree Finder. 1963. Nature Study Guild Publishers, Box 972, Berkeley, CA 94701.

Watts, May Theilgaard and Tom Watts. Winter Tree Finder. 1970. Nature Study Guild Publishers, Box 972, Berkeley, CA 94701.

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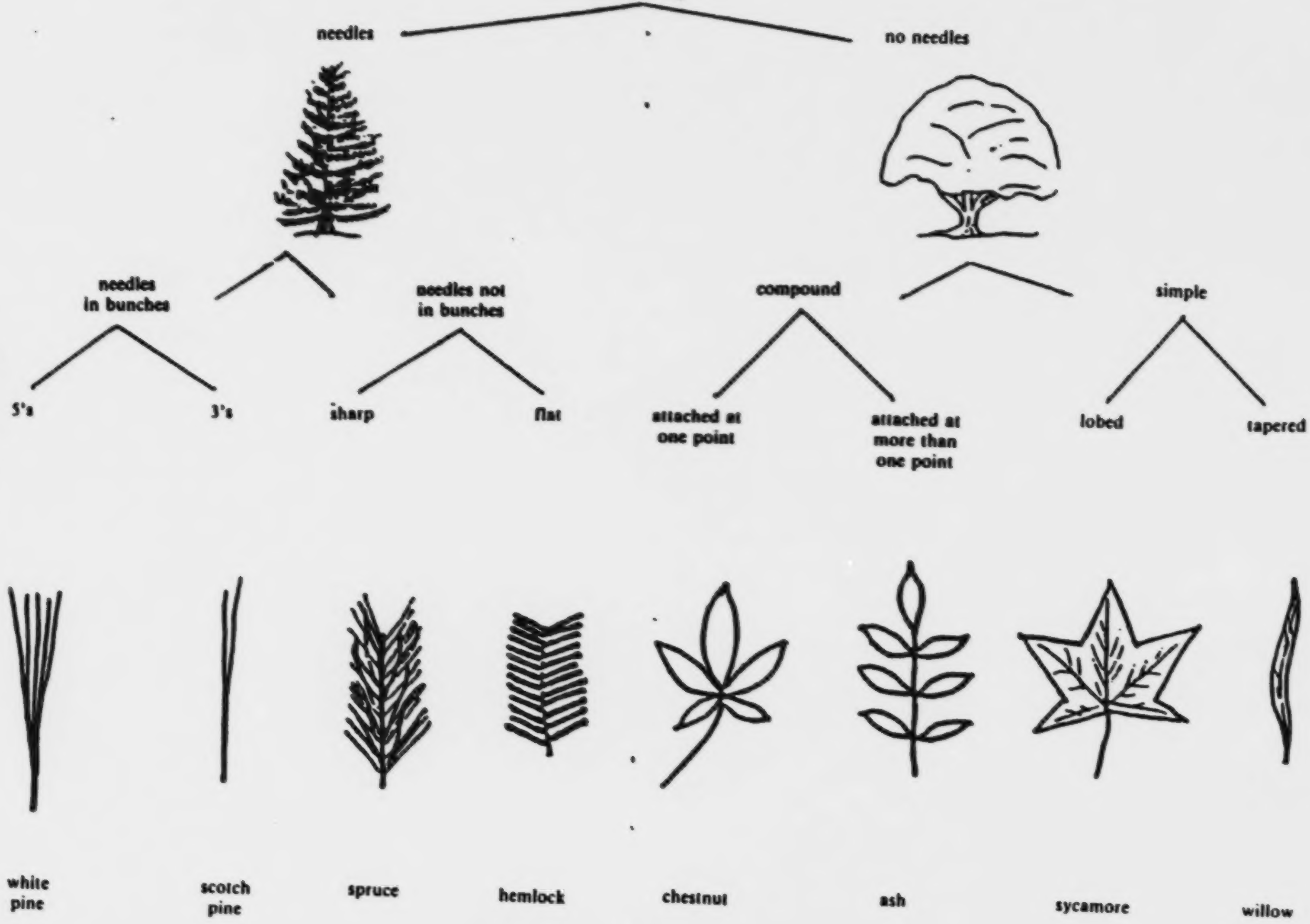
Appendix
Sample Key


needles
no needles
needles in bunches
needles not in bunches
compound
simple
5's
3's
sharp
flat
attached at one point
attached at more than one point
lobed
tapered
white pine
scotch pine
spruce
hemlock
chestnut
ash
sycamore
willow

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A NEW LOOK IN GRANDMA'S BUTTON BOX

Experiences with Buttons For Grades K-2

MATHEMATICS AND SCIENCE SKILLS, CONCEPTS, AND PROCESSES:

Classification, seriation, recording, graphing, describing, naming shapes, counting, learning mathematical symbols, estimating, problem solving. (An objective is listed for each activity.)

OBJECTIVES: Listed for each activity

RATIONALE: Buttons are an inexpensive resource readily available to classroom teachers. Using buttons as manipulatives teachers can provide students practice in the use of science processes and in the development of mathematical concepts. Buttons can be sorted and classified by many attributes. The least observant and the most observant student can be successful discovering classification schemes. Teachers can use buttons to help students move from concrete operations to abstract symbolization with counting, computing, place value, patterns, and graphing. Both science and mathematical concepts can be developed in young children using the concrete properties of buttons.

LESSON OUTLINE: Each of the following activities contain objectives, materials, and procedures a teacher may follow in doing the activity.

EXPLORING BUTTONS

Objective: To explore buttons' attributes, similarities and differences. To classify by one or more properties. To experience the joy of discovery.

Procedure: Dump a box of buttons on a table or mat. Students will have 10-15 minutes to explore materials.

Hint: Teacher should observe children exploring materials and record the use of materials by students encouraging ordering, sorting, and group interaction.

ATTRIBUTE PATTERNS WITH BUTTONS

Objective: To observe and classify similar and different attributes. To build patterns using observed and classified attributes. To extend a given pattern.

Materials: A collection of approximately 10 buttons per student, strips of paper 8" x 2".

Procedure: Each student classifies 10 buttons by a given attribute (color, texture, luster, size, shape, or number of holes.) Each student then makes and records a repeatable pattern using the given attribute. Share patterns with other students to extend the pattern.

ESTIMATING WITH BUTTONS

Objective: To estimate number of objects in two containers.

Materials: Two jars of different capacities full of buttons

Procedures: Students will estimate the number of buttons they believe are in the smallest jar and record number. One student counts the buttons and students check answers for accuracy. They then estimate number in second jar and record answers. Teacher tells the correct number in the second jar and students check answers to see if they are closer to the correct number the second time.

Hints: Answers could be graphed on large graph paper each time estimation is made to see if the class as a whole was more accurate the second time. Graph answers in groups of 5 or 10 to avoid a graph that is too large.

WEIGH-A-BUTTON

Objective: To develop concept of heavier/lighter and measurement skills.

Materials: A balance and small collection of buttons for each pair of students. A set of 10 cards, five saying "heavier" and five saying "lighter".

Procedure: Students work in pairs. Each student grabs a handful of buttons and places them on one side of the blanace. One student then chooses a card. The student whose handful matches the card is the "winner."

PREDICT-O

Objective: Developing predicting and classifying skills

Materials: Any number of students can play. A bag or sock containing 15 or more buttons of three different colors (example: 3 red, 5 blue, 7 yellow). The buttons should be exactly alike except for the color difference. Label graph paper with the three colors. Matching crayons.

Procedure: Players take turns drawing a button from the bag. Then using the crayon that matches the color of the button, color the appropriate area of the graph paper. Return the button to the bag. When 10 buttons have been drawn try to answer these two questions: Which color would you predict you would find most often? Least often? Write down the predictions. Dump the buttons out and see if the predictions are correct.

I SPY A BUTTON

Objectives: Classifying and describing.

Materials: Any number of students may play. A collection of .20-24 buttons. Number used depends on ability level.

Procedures: All buttons should be visible in one or two lines. Children take turns describing a particular button by identifying one property at a time (not location) accurately enough for the other to identify the button. (Hint: To make it harder, describe the button next to the button students are to name.)

REFERENCES: SCIS Material Objects Teacher's Manual, ESS Attribute Block Activities Teacher's Manual. *For the Love of a Lady Bug* by Imogene Forte and Joy MacKenzie, Incentive Publications, 1978.

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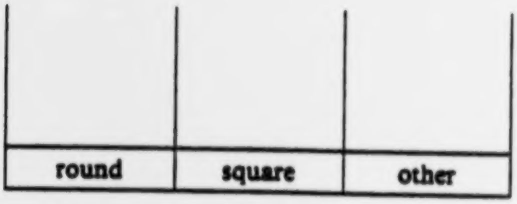
GRAPHING WITH BUTTONS

Objective: To graph attributes of a group of buttons.

Materials: Each child has 1-3 buttons depending on size of group. A large teacher-made bar graph.

Procedure: Choose one attribute to classify buttons. (This can vary each time the activity is done.) Each child puts a button in the appropriate graph bar for the attributes his/her button possesses.

Example: shape



PROPERTY PATTERNS

Objective: To identify properties of buttons. To practice fine motor and visual discrimination skills.

Materials: Buttons, carpet, thread and needles (threaded) or shoelaces. Task cards.

Procedure: Students string buttons according to property on task card. Cards can have no reading or reading depending on the level of students. Sequence of properties may be repeated to complete a design.

Example: Task Cards

# 1	red	blue	
# 2	white	not white	
# 3	wooden	plastic	
# 4	metal	wooden	plastic
# 5	shank	two holes	four holes

SSMILES

The Planets in Perspective
Grades 6-8

Mathematics Concepts/Skills

Understanding of large numbers, ordering of numbers, rounding, estimation, ratio, proportion, variable, scaling, calculator use, problem solving

Science Concepts/Skills

Planetary distance and size relative to each other and the sun, measurement, modeling, hypothesizing

Prerequisite skills:

Counting, division, determining units of measurement, ability to assess reasonableness of a model

Objective:

The students will explore ways to make a "reasonable" model of our solar system in terms of the planets' distances (and, as an option, sizes) relative to each other and to the sun by using appropriate scaling techniques. The class will then make the distance model using the perforated edges of computer paper.

Rationale:

Content background: It is very difficult for most students at this age level to comprehend the vast distances between objects in space. Usually books depict the nine planets of our solar system in order from the sun but at equally-spaced intervals from the sun.

To help students get a better idea of the relative distances in the solar system, the class will consider ways to "scale down" these values so that the distances between the planets can be reasonably represented by lengths of perforated edges from computer paper. Students should suggest various possibilities for scaling so that the model can be displayed in the classroom. Assessing the reasonableness of any particular scale is part of the exploration and problem solving process here.

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As an additional and worthwhile activity, students can also explore ways to represent the relative sizes of the planets and the sun and place these models on the same display area.

Finally, students can do their own research on the solar system and be asked to provide the distances (and diameters) required for this activity, but this information is included on page 6.

Lesson Outline:

Time: 2 class periods of approximately 50 minutes each (without extensions)

Materials/Supplies for Each of the Nine Groups:
Computer paper—performated edges of up to 20 sheets, calculator, colored marker, copy of the table containing the distance each planet in our solar system is from the sun, copy of the SSMILES worksheet, piece of newspaper, transparent tape. (Optional: colored construction paper or posterboard.)

Preparation: Separate the students into nine groups, one responsible for each planet. Decide ahead of time how much display area the final model will occupy—for example, a blackboard, a bulletin board, or a span of wall. Cover the area with dark paper and make a yellow circle to represent the sun. (If the activity with the diameters will be included, the sun's scaled size with respect to the planets' scaled diameters would be appropriate.) Also, make a transparency of the SSMILES worksheet, page 7.

Procedure:

1. As an introduction, discuss with students their experiences with scaling. Examples may include: reading maps; constructing model cars, boats, airplanes, homes; architectural blueprints; and interior design floor plans.

2. Give each group a perforated edge of 1 sheet of computer paper and a copy of the data table. The students should arrange the planets in sequential order (ascending or descending) based upon distance from the sun. The students should then round the distances in the table to a reasonable amount (e.g., the nearest million).

3. Discuss the task of scaling large distances to a relatively small area. An example from another context such as approximate distance children live from school may be helpful. Students could construct a scale drawing of five distances on the chalkboard.

4. Discuss the task of scaling the large planetary distances to a relatively small area such as a bulletin board. Try one example that will generate an "unreasonable" model for your display area. Begin by letting the distance from the center of one hole to the center of the next, which we will call one astronomical unit (AU)*, represent 1000 miles.

   Experiment with another "unreasonable" example such as one AU representing 10,000 miles, and discuss the use of ratio and proportion here. For example:

$$\frac{1 \text{ astronomical unit}}{10{,}000 \text{ miles}} = \frac{\times \text{ astronomical units}}{3{,}658{,}000{,}000 \text{ miles}}$$

   would determine the number of these astronomical units needed to represent Pluto's distance from the sun.

5. Have each group brainstorm for part of the class time to generate an astronomical unit that will allow the entire solar system to fit into the display area.

6. Discuss each groups' ideas—possibly by listing each suggested representative on the chalkboard—and then, as a class, decide on the one scale that would seem to best accomplish the goal.
   (Note to the teacher: The total length of the display area would represent the distance from the sun to Pluto and the distances of the other planets could be scaled accordingly.)

7. Assign one planet to each group and have each group select one colored marker.

8. Based on the class scale, each group should then calculate the number of astronomical units needed to represent the distance their planet is from the sun.

9. One person from each group should record this result on the teacher's transparency and all students should use this to fill in their own tables.

*There are 22 astronomical units (AUs) per strip, which includes 21 AUs between the holes within the strip, and one-half unit on either end of the strip.

10. The students in each group should now calculate the actual number of strips they will need to represent the number of astronomical units their planet is from the sun (there are 22 astronomical units per strip), count them, and color the strips with the colored marker using the newspaper as a desk cover. The strips should then be connected together with transparent tape.

11. Several people from each group should then place the group's colored strip on the display area (with respect to the sun) and label the planet at the end of the strip.

Evaluation:

Class discussions or written evaluation will help determine if students understand the importance, difficulties, and potential of model building as well as the actual representation of the planetary distances in the solar system. A written evaluation may involve a scaling problem from a different context such as representing major cities in the United States or across the world.

Teacher Notes:

On a bulletin board display area of approximately six feet wide, a scale based upon one astronomical unit representing 30 million miles would be reasonable.

Teacher Extensions:

1. Another display area (e.g., a gym wall) could be considered so that students need to revise the astronomical unit and could share their class activities with the rest of the school.
2. Students could explore the possibility of letting the distance from any one of the planets to the sun be one astronomical unit and then representing all the remaining distances relative to that AU.

3. The relative sizes of the planets (and the sun) can easily be incorporated into this activity and add another dimension to the display. (An extra 20-30 minutes of class time should suffice.) Again, the class should develop a suitable scale, perhaps by initially rounding the diameters given in the table to the nearest thousand and using the diameter of Pluto as the unit. Each group can determine the number of strips (taped together, if necessary) needed to represent the diameter of their planet. The students should then be given a piece of construction paper or posterboard, the color matching that of their distance strip. To make a circle of appropriate size, the students can punch a hole in the center of their diameter strip with a pencil and revolve the strip around this center many times, marking both ends each time. The planets can then be displayed at the appropriate distances on the display area. The SSMILES worksheet and table on page 6 contain the necessary information.

4. Students could explore the possibility of using the same scaling or astronomical unit for both the planetary distances and the planetary size (i.e., diameters). Would this be reasonable? Students could discuss their reasoning.

5. The same activities could be done using kilometers for the planetary distances and sizes.

References:

Branley, F. M. (1981). The planets in our solar system. New York, NY: Thomas Y. Crowell Publishing Company.

Note: Any book on our solar system should contain the information needed. However, if research is not deemed vital here, the table on the following page contains all the necessary information and can be duplicated for the students, as suggested in the "preparation" section.

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Handouts: Student worksheets.

PLANET DIAMETER	ACTUAL MEAN DISTANCE FROM SUN IN MILES (ROUNDED TO NEAREST THOUSAND)	DIAMETER IN MILES
Earth	92,752,000	7,909
Jupiter	482,546,000	88,536
Mars	141,298,000	4,208
Mercury	35,898,000	3,026
Neptune	2,787,892,000	30,690
Pluto	3,658,000,000	1,860
Saturn	884,740,000	74,400
Uranus	1,779,152,000	32,116
Venus	67,084,000	7,504

SSMILES
DATA TABLE

PLANET	ACTUAL MEAN DISTANCE FROM SUN IN MILES (TO NEAREST MILLION)	DISTANCE IN MODEL	(OPTIONAL) DIAMETER IN MILES	(OPTIONAL) DIAMETER IN MODEL

Scale used for distance model:

(Optional)
Scale used for size (diameter) model:

SSMILES

Feeding Pleasure Horses
Grades 4-9

Mathematics Concepts/Skills

graphing, interpreting graphs (e.g., slopes), scaling, prediction, problem solving, parts per 100, measurement division

Science Concepts/Processes

nutrition, energy, work comparing, hypothesizing, organizing and reporting data, inferring

Prerequisite Skills:

Rounding, approximation, common fractions and decimal equivalents [(1/4, .25), (1/2, .50)], use of calculator

Objective:

Using information about the daily hay and feed needs of horses, students will complete a chart showing the daily ration for five pleasure horses. This chart will include a ration related to a light, medium, and heavy workload. Students will construct and interpret the graphs showing hay and feed ration per 100 lbs. of weight for each horse and each workload.

Rationale:

Educators have recommended that middle school learners be actively involved in the learning process, study high-interest material related to their daily lives, and benefit from investigations involving nontraditional school environments. The idea for this SSMILES was generated by a seventh grade class as an example of their "real-life integration of science and mathematics."

The general relationship between proper nutrition, health, and energy level related to work requirements can be applied to all animals including man. Graphs can enable students to represent and organize data, understand relationships, and make inferences about the requirements and benefits of proper nutrition.

Content Background

Plant eating animals such as horses need to eat constantly because the nutrients in plants are less concentrated than in meat. Proper nutrients are very important when feeding horses because they provide energy to do work. It is very important to use knowledge and good judgment when developing a daily ration for a pleasure horse. The work of a pleasure horse is to provide recreation and sport for people. Examples of pleasure horses include Arabian, Appaloosa, mixed breed, Morgan, quarter horse, Shetland pony, standard bred, Tennessee walker, thoroughbred, and Welch pony. The energy needs of a pleasure horse depend on weight and the amount of work performed. A properly balanced daily ration for a pleasure horse should include feed, hay, water, and salt. The feed should contain the following nutrients: a) proteins to develop protective tissue and body structures; b) carbohydrates and fats to provide energy for maintenance, growth, reproduction, and work; and c) calcium and phosophorus to build bones and teeth. The weight of hay is related to the weight of feed and the required energy level. Increasing the weight of feed while decreasing the hay (roughage) will give the horse extra energy. Horses require between 10-20 gallons of water per day. The amount will depend upon the weather and the workload. One-half to two ounces of salt (sodium chloride) per day is necessary for proper digestion of the food ration. This will vary depending on the workload and the weight of the horse. The signs of a healthy, well-fed pleasure horse include alertness; good appetite; sleek oily coat; pliable elastic skin; pink, moist membranes around lower lip; and trim body, legs, and hooves.

Lesson Outline:

Time: Four to five 45 minute periods
Materials/Supplies per student:
  Hay and Feed Ration by Workload Information Chart
  Feeding Schedule Chart for student completion
  Scaled graph paper
  Non-scaled graph paper

Procedure:

1. Identify horses as plant eating mammals and discuss with students their experiences with horses and the dietary needs of horses. Emphasize the relationship between proper nutrition, health, and energy level.

2. Discuss the daily ration needs of pleasure horses. This information appears in the Teacher Notes and can be given to the students or assigned for individual or group research. References are provided.

3. Give each student the Hay and Feed Ration by Workload Information Chart. These are minimum hay and feed requirements. Discuss the chart with the students. Observe and discuss any patterns or relationships.

4. Give each student the Feeding Schedule Chart. Using calculators, the students should calculate and fill in the weight of hay and feed for each horse for each workload. Students could brainstorm how to determine the weight of hay and feed needed. For younger students, base 10 blocks could be used to represent the weight of the horse. The number of groups of 100 could be counted to determine how many units of 100 are in the horse's weight (i.e., measurement division). Both younger and older students should use the calculator to do the mathematical computations. Older students could use the calculator to do multiple mathematical operations: divide the weight of each horse by 100 and multiply by the appropriate workload decimal. A completed chart is provided.

5. Have students make a graph displaying the weight of the five pleasure horses. In the lower grades, the scaling could be provided and students could explore the relationship between bar graphs and line graphs. In the upper grades, students could investigate the use of different scaling. (See sample Graph 1.)

6. Possible questions for discussion include:

a. Which horse weighs the least? What is the approximate weight of this horse? (a) 500 pounds, (b) 600 pounds, (c) 700 pounds, (d) 800 pounds.

b. Which of the horse(s) weigh more than twice as much as Fire?

7. Have students select a horse and construct a graph showing the weight of feed and the weight of hay needed for different workloads. For an example of a bar graph (for lower grades) and a line graph, see sample Graph 2 and Graph 3. Unscaled graph paper can be used by students in the upper grades to devise their own scaling. Students could use a variety of ways to differentiate between the hay and feed graph lines.

8. These graphs could be produced on an overhead transparency using different color transparency pens, one for each horse, so that all five horses could easily be compared by placing one transparency on top of another.

9. Possible questions for discussion include:

a. Which of the workload(s) require the most feed? Why? Encourage answers that involve both the horse's ration needs and interpretation of the graphs. A discussion relating the slant of the line and a zero, positive, or negative slope would be appropriate.

b. Which of the workload(s) require the least hay? Why? Encourage answers that involve both the horse's ration needs and interpretation of the graphs. A discussion relating the slant of the line and a zero, positive, or negative slope would be appropriate.

c. What happens when the workload changes from light to moderate? moderate to heavy?

d. What does it mean when the line on the graph starts in the upper left and ends up lower and on the right? A discussion relating the slant of the line and a zero, positive, or negative slope would be appropriate.

e. What does it mean when the line on the graph starts in the lower left and ends up higher and on the right? A discussion relating the slant of the line and a zero, positive, or negative slope would be appropriate.

f. When would the owner of the horses have to use the most hay? the most feed?

10. Students could develop another graph to show the relationship between the weight of the horse and the weight of the hay and feed for each workload. (See sample Graph 4.)

11. Possible questions for discussion include:

a. How does the weight of hay needed by the horse relate to the weight of the horse? A discussion relating the slant of the line and a zero, positive, or negative slope would be appropriate.

b. Which requires more feed: a 600 pound horse doing heavy work or a 1000 pound horse doing moderate work?

c. How many pounds of hay would be needed for a 1125 pound horse doing light work? (approximately 14 pounds)

d. How many total pounds of hay and feed would be needed for a 1000 pound horse doing light work? (approximately 15 pounds) doing heavy work? (approximately 20 pounds)

e. What weight of feed would be needed for a 1700 pound horse doing moderate work?

12. Many other questions could and should be generated to describe the horse's ration (hay and feed) related to workload and weight and provide opportunities for students to learn and practice graphing skills (constructive and interpretive).

Evaluation:

Students will be evaluated on their Feeding Schedule Chart; their graphs; and discussion questions about the relationship between horse body weight, hay and feed ration, and workloads; the use of graphs to organize and report data; interpreting graphs (slope to infer relationships); and prediction using graphs.

Teacher Notes:

1. Students could write a computer program that would calculate the daily ration of hay and feed for any weight of horse. (See Feeding Your Horses by John Atherton).
2. Students could research the cost of hay and feed and then determine the daily, weekly, monthly, or annual cost for feeding the five pleasure horses listed in this lesson.
3. Students could explore and graph the relationship between water and salt intake of horses and the workload.
4. Students could research and graph the hay and feed rations of other odd-toed mammals such as zebras, tapiers, and rhinos.
5. Students could research and graph the relationship between daily ration and workloads for other animals. For example, they could research the dietary needs and graph the daily ration for "pet dogs", "show dogs", and "work dogs."
6. Graphing techniques may be varied greatly in this lesson. Students could explore, discuss, and interpret graphs using different variables, changing variable location related to the x-axis or y-axis, and different scaling methods.

Acknowledgments:

We would like to thank Section 7-6, seventh grade mathematics students at Utica Jr. High School in Utica, Ohio, for generating this example of integrating science and mathematics from their life experiences.

Our thanks are also extended to John Atherton for writing the computer program to compute the weight of hay and feed related to the weight of the horse.

We wish to express our gratitude to Lowell White of Sandy Glen Farm, Performance Arabian Horses, Oakley, California for his consultation and advice.

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Postscript:

Any resemblance to actual horses, their names, and their weights is purely intentional.

HAY AND FEED RATION BY WORKLOAD

INFORMATION CHART

	LIGHT WORK	MODERATE WORK	HEAVY WORK
HAY	1 1/4 (1.25)	1 (1.0)	1 (1.0)
FEED	1/4 (.25)	1/2 (.5)	1 (1.0)

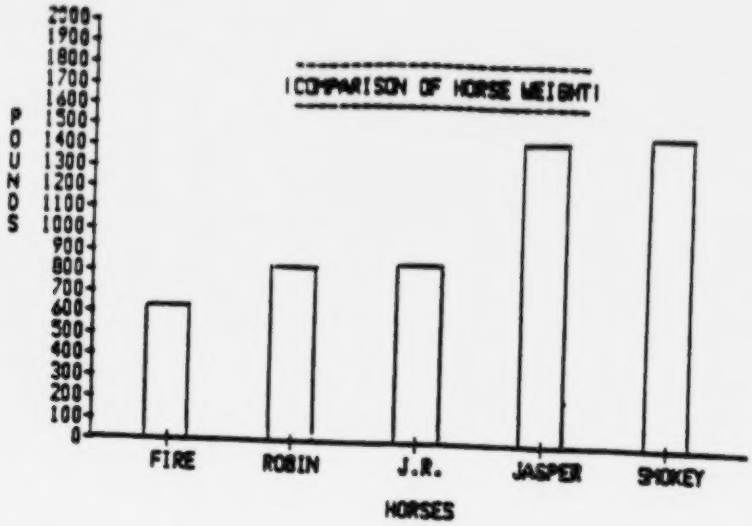
FEEDING SCHEDULE CHART

HORSE		-LIGHT WORK-	-MODERATE WORK-	-HEAVY WORK-
"FIRE" 632 LBS. QUARTER HORSE	HAY			
	FEED			
"JASPER" 1460 LBS. TENNESSEE WALKER	HAY			
	FEED			
"SMOKEY" 1500 LBS. QUARTER HORSE	HAY			
	FEED			
"J. R." 862 LBS. QUARTER HORSE	HAY			
	FEED			
"ROBIN" 842 LBS. MORGAN	HAY			
	FEED			

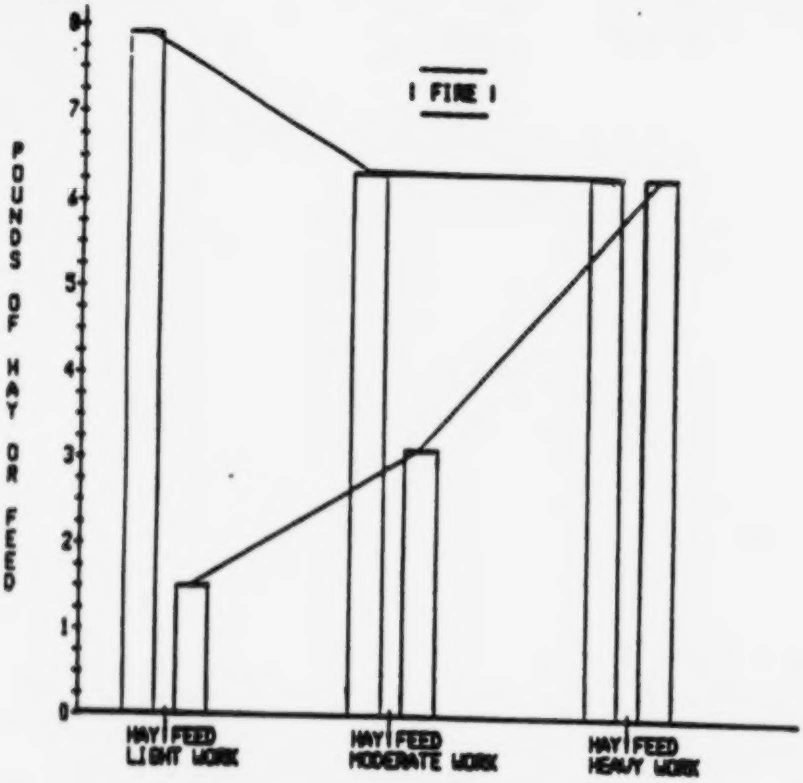
FEEDING SCHEDULE CHART

HORSE		- LIGHT WORK-	-MODERATE WORK-	-HEAVY WORK-
"FIRE" 632 LBS. QUARTER HORSE	HAY	7.90 LBS.	6.32 LBS.	6.32 LBS.
	FEED	1.58 LBS.	3.16 LBS.	6.32 LBS.
"JASPER" 1460 LBS. TENNESSEE WALKER	HAY	18.25 LBS.	14.60 LBS.	14.60 LBS.
	FEED	3.65 LBS.	7.30 LBS.	14.60 LBS.
"SMOKEY" 1500 LBS. QUARTER HORSE	HAY	18.75 LBS.	15.00 LBS.	15.00 LBS.
	FEED	3.75 LBS.	7.50 LBS.	15.00 LBS.
"J. R." 862 LBS. QUARTER HORSE	HAY	10.78 LBS.	8.62 LBS.	8.62 LBS.
	FEED	2.16 LBS.	4.31 LBS.	8.62 LBS.
"ROBIN" 842 LBS. MORGAN	HAY	10.52 LBS.	8.42 LBS.	8.42 LBS.
	FEED	2.10 LBS.	4.21 LBS.	8.42 LBS.

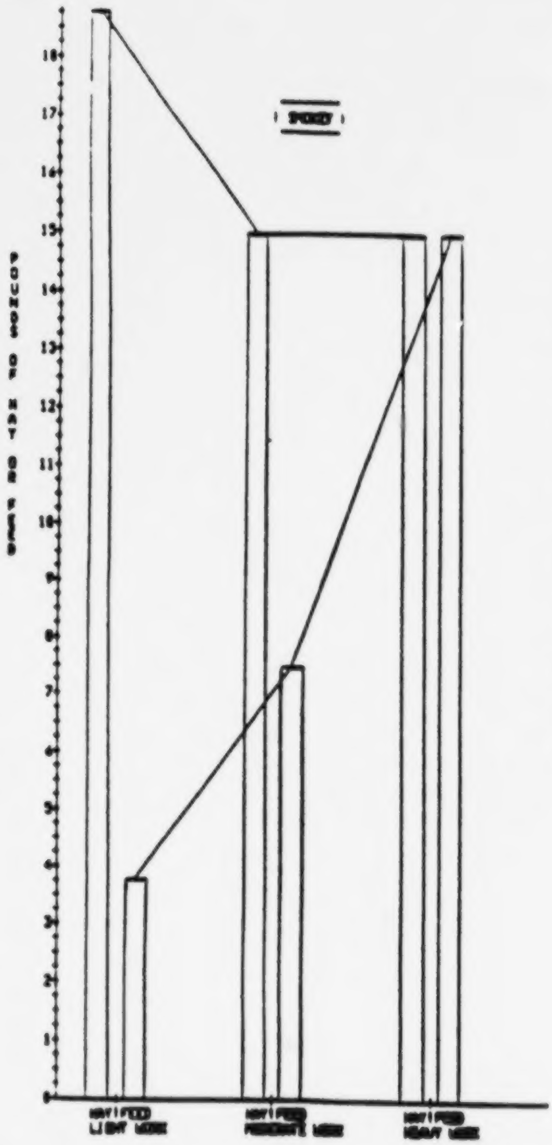
Graph 1



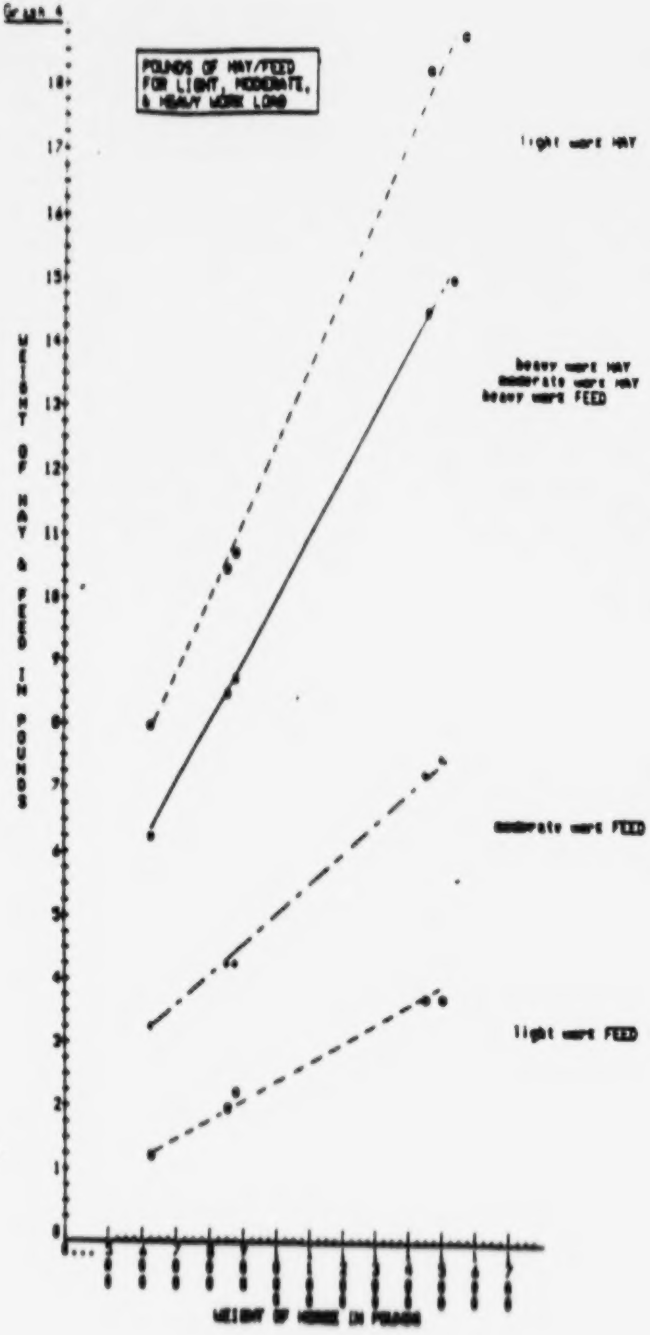
Graph 2



Graph 3



Graph 4



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FEEDING YOUR HORSES
BY
JOHN ATHERTON

```
10  HOME : VTAB 10
20  PRINT "          FEEDING YOUR HORSES
30  VTAB 12: PRINT "                    BY
40  VTAB 14: PRINT "              JOHN ATHERTON
50  VTAB 16: PRINT "                10/22/87
60  FOR X = 1 TO 4000: NEXT X
70  HOME : VTAB 8
80  PRINT "THIS PROGRAM IS MADE TO HELP YOU.
90  VTAB 10: PRINT "IT WILL TELL YOU HOW MANY POUNDS
100  VTAB 12: PRINT "OF HAY AND FEED TO GIVE
11J  VTAB 14: PRINT "YOUR HORSE EACH DAY..
120  VTAB 23: HTAB 7
130  INPUT "PRESS RETURN TO CONTINUE.";R$
140  REM  W = TYPE OF WORK
150  REM  F = TYPE OF FOOD
160  REM  P = WEIGHT OF HORSE
170  REM  X/Y = FOR/NEXT VARIABLES
180  REM   F(2,4) = FOOD/100 POUNDS
190  REM     I WHAT TYPE OF FOOD
200  REM         ITYPE OF WORK
210  DIM F(2,3)
220  DEF  FN S(DUMMY) = P * F(F,W) / 100
230  FOR Y = 1 TO 2
240  FOR X = 1 TO 3
250  READ F(Y,X)
260  NEXT X,Y
270  HOME : VTAB 8: PRINT "WORK TABLE"
280  PRINT "-----------------------
290  PRINT " 1. LIGHT WORK"
300  PRINT " 2. MODERATE WORK"
310  PRINT " 3. HEAVY"
320  PRINT " 4. ALL DONE"
330  PRINT : INPUT "WHAT TYPE OF WORK HAS YOUR HORSE DONE?";W
340  IF W > 4 OR W < 1 THEN 270
350  HOME : IF W = 4 THEN  END
360  VTAB 8: PRINT "FOOD TABLE"
370  PRINT "-------------------------"
380  PRINT " 1. HAY"
390  PRINT " 2. FEED"
400  PRINT : PRINT "WHAT TYPE OF FOOD ARE YOU GOING TO GIVE "
410  INPUT "YOUR HORSE?";F
420  IF F > 2 OR F < 1 THEN 360
430  HOME : VTAB 8: HTAB 8
440  INPUT "WHAT IS YOUR HORSES WEIGHT?";P
450  HOME : VTAB 10: HTAB 10: PRINT "CALCULATING..."
460  FOR X = 1 TO 1000: NEXT X
470  PRINT : PRINT "YOUR HORSE SHOULD BE FED, "
480  IF F = 1 THEN  PRINT  FN S(0);" POUNDS OF HAY."
490  IF F = 2 THEN  PRINT  FN S(0);" POUNDS OF FEED."
500  VTAB 23: HTAB 7
510  INPUT "PRESS RETURN TO CONTINUE";R$
520  GOTO 270
530  REM  DATA FOR HORSES GIVEN HAY
540  REM  AFTER WORK.
550  DATA    1.25,1,1
560  REM  -----------------------
570  REM   DATA FOR HORSES GIVEN FEED
580  REM  AFTER WORK
590  DATA    .25,.5,1
```

SSMILES

Temperature Measurement

Grades 5-9

Mathematics Concepts/Skills

graphing, scaling, interpreting graphs (e.g., slope, linearity, intersection), prediction

Science Concepts/Processes

temperature, heat, Fahrenheit, Celsius, freezing point, boiling point, standards, collecting and organizing data, graphic interpretation

Prequisite Skills:

Use of coordinate system for graphing simple points and experience reading and measuring with linear scales.

Objectives:

1. to translate temperature data into a graphic representation,
2. to interpret the graphic representation of data,
3. to explore the relationships between the Fahrenheit (°F) and Celsius (°C) temperature scales,
4. to relate the concepts of slope, intercept, and linearity to the relationships between the Fahrenheit (°F) and Celsius (°C) temperature scales.

Rationale:

Temperature measurement and interpretation is a basic skill for everyday living and for laboratory science exploration. The two common temperature scales encountered by students are the Fahrenheit and Celsius scales. In this country the two scales are used in a variety of ways. Sometimes you see only the Fahrenheit temperature, sometimes only the Celsius temperature, and sometimes you see them both. To understand information related to energy exchange and heating in this world it is important to have a basic understanding of the relationship between heat and temperature. Since this relationship is related to the choice of temperature units, the more experience students have with the interrelationship between these units the better intuition they will have. Commonly the students are simply given the mathematical relationship between these scales or a chart to convert from one scale to the other with little or no exploration, on their part, into the determination of the relationships which exist between the scales and the degree units.

Content Background:

The relationship between heat and temperature is a common area of misconceptions. Heat can be thought of as the amount of energy which is present in a substance or transferred from one substance to another. Heat is measured in calories. A (small) calorie is the amount of heat required to raise the temperature of 1 gram of water by 1 degree Celsius (C°). This is a very small unit of heat and would require very large numbers to describe the quantities of heat we often deal with in everyday living. Another unit known as the (large) Calorie has been defined. It is equal to 1000 of the (small) calories defined previously and is referred to as a kilocalorie. The English system of heat measurement is the British thermal unit (BTU) and is the amount of heat needed to raise the temperature of 1 pound of water 1°F. Common household appliances such as clothes dryers, hot water heaters, and air conditioners are rated in BTUs.

We raise the temperature of a substance by adding energy (calories). When energy is added to water it makes the water particles (molecules) move faster. When we place a thermometer in a substance like water, the moving particles strike the thermometer and transfer energy to the thermometer. Inside the thermometer is a very thin column of mercury or in some cases alcohol. As energy is transferred to the thermometer, the particles in this thin column of liquid move faster, with more energy, and expand up the tube. As the particles collide more often and with greater impact with the thermometer, more energy is transferred to the column of liquid in the thermometer and the column moves higher. This energy due to movement of particles is known as kinetic energy and the thermometer measures the average kinetic energy of the particles. Thus temperature is defined as the measure of the average kinetic energy of the particles of a substance.

Temperature is measured in degrees. There are two common temperature scales, the Fahrenheit scale and the Celsius scale. On the Fahrenheit scale, the freezing point of water is 32°F and the boiling point of water is 212°F. On the Celsius scale, the freezing point of water is 0°C and the boiling point of water is 100°C. Since the difference between freezing to boiling on the Fahrenheit scale is 180F°, the "size" of a F° would be 1/180th of that interval or "distance." Similarly, since the difference between freezing to boiling on the Celsius scale is 100C°, the "size" of a C° would be 1/100th of that interval or "distance."

Lesson Outline:

Time: Two to four 45 minute periods

Materials/Supplies per student or team:

- 1 — Fahrenheit thermometer (alcohol)
- 1 — Celsius thermometer (alcohol)
- 2 — cups of water
- 1 — cup of hot coffee or water
- 8 — ice cubes
- 1 — roll of paper towels
- 1 — sheet of 1cm graph paper
- 1 — straight edge or ruler
- 2 — colored pens or pencils (red & blue)

Materials/Equipment per classroom:

- 1 — overhead transparency
- 2 — transparency pens (red & blue)
- 1 — transparency of blank 1cm graph paper

Procedure:

This lesson will provide students with a hands-on activity to measure temperature with two different scales, represent the data in graphic form, explore the differences and similarities in the units and the scales, to identify points of intersection, and facilitate student understanding of the relationship of temperature to heat. The activity can be used by individual students or teams of students. Students complete the student worksheet as they do the activity and teacher notes provide additional guidance.

Teacher Notes:

1. A teacher-led discussion or student research assignment related to the freezing point and boiling point of water for Fahrenheit and Celsius should precede the use of the Student Worksheet. Discuss

with students their experiences and current knowledge about heat, temperature, and the Fahrenheit and Celsius scales.

2. For younger students, the teacher may wish to provide graph paper with the scaling already marked for the °F and the °C temperatures. It is recommended that the Fahrenheit scale be assigned to the vertical (Y-axis) and the Celsius scale be assigned to the horizontal (X-axis). For the older students, you may wish to leave the choice of axis and scaling up to them.

3. The teacher can use the overhead projector, a transparency of the graph paper, and the colored transparency pens to discuss and summarize the student results.

4. For questions 11 to 13 on the Student Worksheet, the students should be helped to recognize that there are more Fahrenheit degrees than Celsius degrees between the freezing point and the boiling points of water. Since there are fewer Celsius degrees than Fahrenheit degrees to measure the same range of temperature, the Celsius degrees have to be larger than the Fahrenheit degrees.

5. There are a number of approaches to solving the problem posed in question 14 on the Student Worksheet. They vary in strategy and in difficulty. Three approaches are outlined here:

a. the students can find the point on the line they have drawn where the Fahrenheit and Celsius temperatures are identical by visual inspection. They will probably need a straight edge or ruler to make their determination more precise.

b. the students can plot the pairs of points where the Fahrenheit and Celsius temperatures are the same [e.g., (0°F, O°C), (40°F, 40°C), etc.] on the graph with the original data. When these new points are plotted and then connected they should result in a straight line that will intersect the line representing the students original data. The point of intersection is the point where the temperature readings of the two scales are identical.

c. the formulas which relate the Fahrenheit and Celsius scales can be used to determine the common point as follows:

Given: $^{\circ}F = (9/5)*(^{\circ}C) + 32$
$^{\circ}C = (5/9)*(^{\circ}F - 32)$
For the readings to be the same we know that:
$^{\circ}F = {}^{\circ}C$
Using substitution we have:
$(9/5)*(^{\circ}C) + 32 = (5/9)*(^{\circ}F - 32)$
Again because the readings will be the same at the point in question (substituting °C for °F) we have:
$(9/5)*(^{\circ}C) + 32 = (5/9)*(^{\circ}C - 32)$
$(9/5)*(^{\circ}C) + 32 = (5/9)*(^{\circ}C) - (5/9)*(32)$
$(9/5)*(^{\circ}C) - (5/9)*(^{\circ}C) = -(5/9)*(32) - 32$
$(81)*(^{\circ}C) - (25)*(^{\circ}C) = -(25)*(32) - (45)32$
$(56)*(^{\circ}C) = -(800) - 1440$
$(^{\circ}C) = -(2240)/(56)$
$^{\circ}C = -40$
Since: $^{\circ}F = {}^{\circ}C$, thus $^{\circ}F = {}^{\circ}C = -40$

Evaluation:

Students will be evaluated on their completion of the student worksheet and discussion questions.

Extension:

Students can use a computer and a software package which includes a thermistor probe instead of the Fahrenheit and Celsius thermometers. Using the thermistor probe, students can obtain more precise measurements as they complete the student worksheet. Students will need the materials/supplies listed previously with the addition of the following:

Materials/Supplies per class:

Software: Science Toolkit Master Module by Broderbund or Playing with Science: Temperature by Sunburst

Equipment:

1 — Apple IIe/IIc (64K memory) computer and monitor

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STUDENT WORKSHEET

Name: ______________________________ Date _____ / _____ / _________

Procedure:

1. Use the thermometers to measure the temperature of each of the following and record the °F and °C for each in the Data Table. Choose two other items for temperature measurement for e. and f.

a. water at room temperature
b. cup of hot coffee/water
c. glass of ice water
d. body temperature
e.
f.

Data Table

	°F	°C
a. Water at room temperature		
b. Cup of hot coffee		
c. Glass of ice water		
d. Body temperature		
e.		
f.		

1. What was the highest temperature? __________ °F __________ °C
2. What was the lowest temperature? __________ °F __________ °C
3. Rank the samples from the highest temperature to the lowest temperature.

highest ____________________
____
____
____
____
lowest ____________________

STUDENT WORKSHEET (CONTINUED)

4. Plot the points represented by the Fahrenheit (°F) and Celsius (°C) temperature pairs on graph paper. Using a straight edge or ruler, draw a straight line which best fits the points and represents the relationship between the two temperature scales.

5. What temperatures on the Celsius scale correspond to each of the following Fahrenheit temperatures?

32°F = (°C)

59°F = (°C)

122°F = (°C)

212°F = (°C)

75°F = (°C)

6. What temperatures on the Fahrenheit scale correspond to each of the following Celsius temperatures?

100°C = (°F)

10°C = (°F)

115°C = (°F)

−15°C = (°F)

25°C = (°F)

7. Use a blue pen or pencil to mark the freezing point of water on the Fahrenheit scale axis and on the Celsius scale axis.

8. Use a red pen or pencil to mark the boiling point of water on the Fahrenheit scale axis and on the Celsius scale axis.

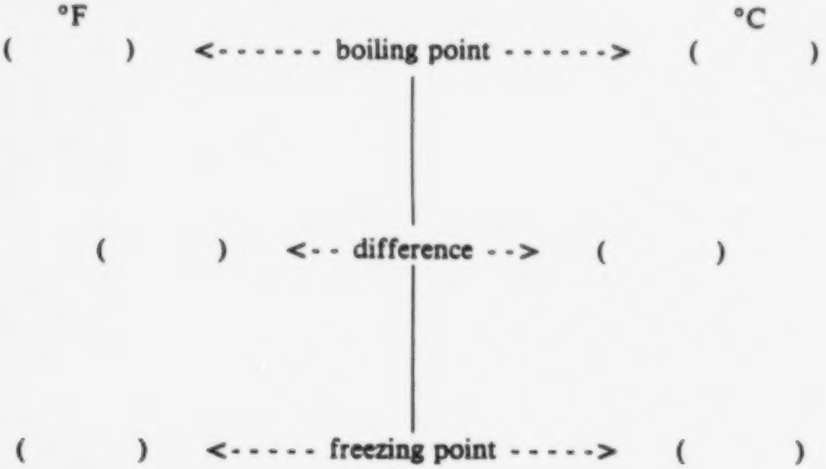
9. How many F° above the freezing point of water is a temperature of 54F°?

10. How many C° above the freezing point of water is a temperature of 54C°?

11. Using the graph, on which scale are there more degrees between the freezing and boiling point and boiling point of water?

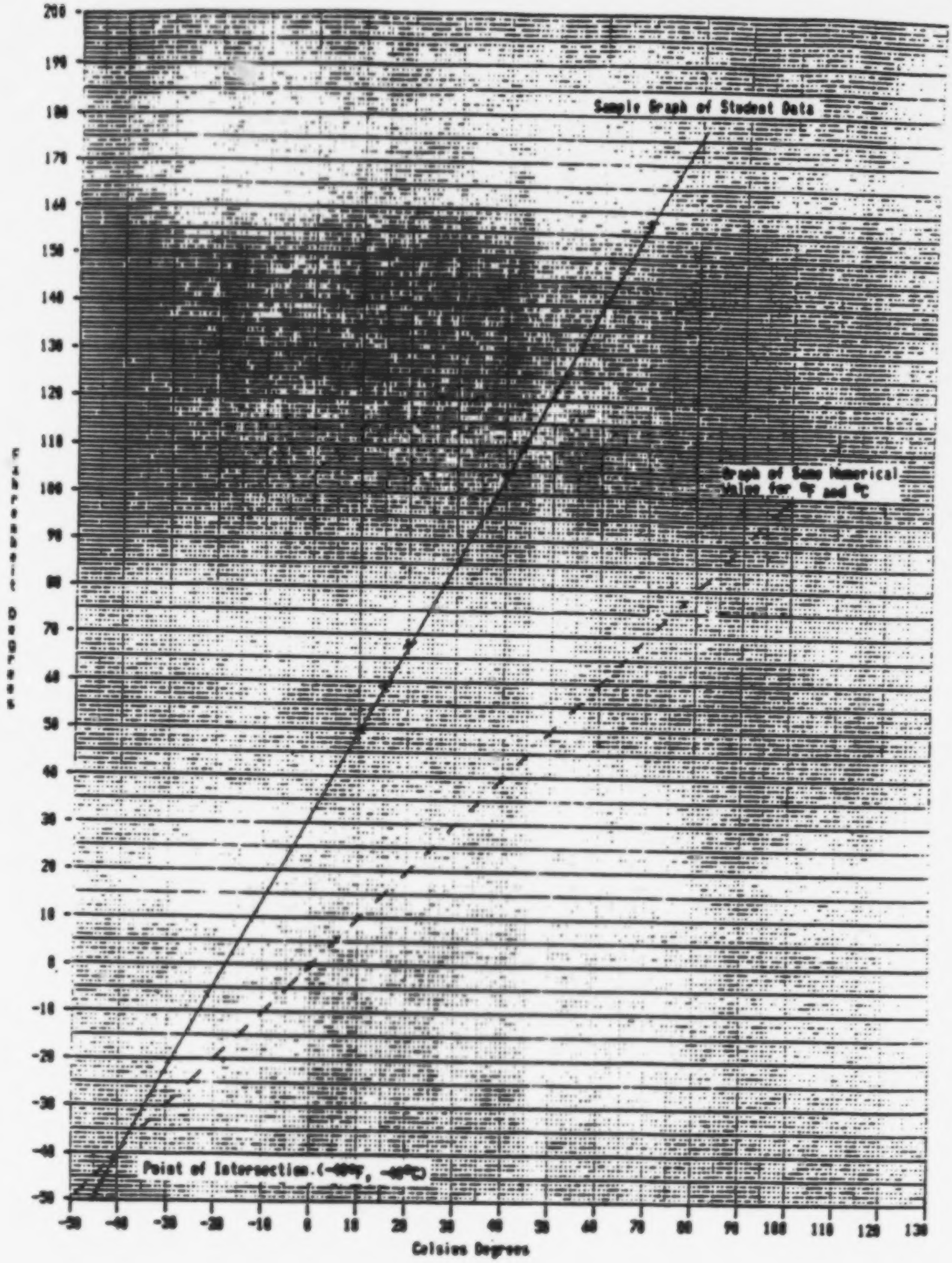
STUDENT WORKSHEET (CONTINUED)

12. Label the following diagram with the appropriate freezing point, boiling point, and temperature differences for the Fahrenheit and Celsius scales.


°F
°C
( ) <------ boiling point ------> ( )
( ) <-- difference --> ( )
( ) <----- freezing point -----> ( )

13. Which degree is "larger," the Fahrenheit or the Celsius? (Which scale requires more energy to change the temperature by one unit, the Fahrenheit or Celsius scale?)

14. Based on this data, predict at what temperature are the readings for the Fahrenheit and the Celsius scales the same?



School Science and Mathematics
Volume 88 (6) October 1988

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SSMILES
12
Bird Parts and Problems
Grades 1-3

Mathematics Concepts/Skills

counting
object, picture and bar graphs
using tree, Carroll and Venn diagrams

Science Concepts/Processes

adaptations of birds
hypothesizing

observing, inferring, comparing,
classifying, inductive reasoning,
predicting

Objective: By tracing and fitting different parts of birds together, the students will assemble birds corresponding to living conditions, and will classify and graph them according to different characteristics.

Rationale:

Interrelationship of Skills and Concepts: This activity focuses on the student's use of intellectual skills such as observing, comparing, classifying, inferring, and predicting which are essential skills in both mathematics and science. A powerful aspect of this activity is the use of inductive reasoning to put bird parts together to form a particular bird rather than to focus on the memorization of the names of different birds. Tree, Carroll, and Venn diagrams are used to help the students classify their birds. This activity is also a good introduction to the construction of bar graphs which begins on a concrete level before moving to a semi-concrete or abstract level.

Content Background: Teachers need not be experts on birds to use this activity. The following information may help teachers guide the students' inductive reasoning about the types of birds they wish to make. Teachers may find more detailed information in bird guides and other resources.

The body of all birds is generally spindle-shaped, like two cones with their bases fitted together. This shape offers little resistance to air during flight and water in diving.

The shape of the bird's bills is related to its food habits. A slender bill allows for probing into cracks, capturing insects, and eating fruits. A wide but delicate bill allows for capturing insects in flight. A stout and conical bill is best fitted for cracking seeds. A curved and sharp-edged bill is characteristic of flesh eaters. A serrated-edged margin on a bill allows birds such as ducks to strain food from the water. A long sharp bill is well-fitted for spearing fish while a pouch-like bill facilitates catching and temporary storage of fish. The use of the bill is complimented by the length, shape and strength of the neck.

The birds' feet are used for running, climbing, body support, food gathering, nest building, and defense. Birds' feet usually have three toes in front and one behind to facilitate perching on twigs and branches. Further adaptations include sharp, curved claws for grasping, webbed feet for swimming, long legs and toes for wading, and stout feet for scratching the ground.

The tails of birds facilitate their flying, perching, and climbing. Broad tails support quick maneuvers in flight. Stiff tails serve as props for birds such as woodpeckers when they cling to the sides of trees.

As the children create their birds, encourage them to discuss why they have chosen certain characteristics. Let them observe birds in their natural habitats and use reference books to check their inferences.

Lesson Outline:

Time: Two or three 30-45 minute periods

Materials/Supplies:

Xerox copies of the Bird Parts for each student
plain white tracing paper

Procedure

Place tracing paper or thin white paper over the Bird Parts page with the body form on it. Use pencil and lightly trace the body form in the center of your paper. Decide on the type of bird you wish to make. Choose the neck, head, and tail that fit your type of bird.

Move the paper around so the body fits to the neck you choose and trace the neck onto the body. Add one of the two heads to the body. Choose a bill and eye and add them to the head. Add feet and a tail to the body. Erase any lines you do not need. Draw in wings and any other details you wish. Darken your completed drawing by going over the lines with your pencil or color your bird with crayons or colored markers.

Try making each of the following birds. Discuss why you chose the bill and feet that you did.

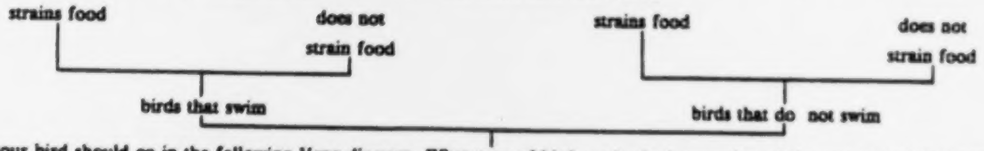
1. Make a bird that lives in the forest, perches on branches and eats insects.
2. Make a bird that wades in the water along streams, lakes, or in marshes and spears fish or frogs for food.
3. Make a bird that perches on branches and eats seeds.
4. Make a hunting bird that catches and eats other birds or small animals.
5. Make a swimming bird that strains food from the water with its bill.
6. Design a bird of your own. Describe where it would live and what it would eat.

After you have designed your bird, cut it out and decide where it would go in the following diagrams. Be prepared to discuss why you placed it where you did.

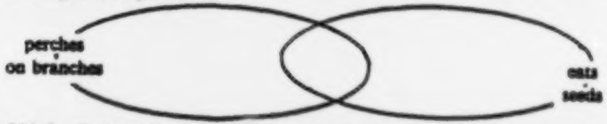
The first diagram is a Carroll diagram. Decide on the proper row and column for your bird. After you and your classmates have placed your birds in this diagram, make up another of your own.

birds that eat insects		
birds that do not eat insects		
	birds that perch	birds that do not perch

The following is a tree diagram. Start your bird at the bottom of the trunk and move up. As you come to each set of branches, decide which way your bird should move. Make other tree diagrams for your classmates to move their birds along.



Find where your bird should go in the following Venn diagram. What type of birds go in the intersection of the two circles? What types of birds go outside both circles? Make other Venn diagrams of your own.



Make graphs to show the types of birds all the students in your class have made. Choose a characteristic such as whether or not the bird eats fish. Have all the children who are holding birds which eat fish stand in one line and children who are holding birds which do not eat fish stand in another. Which line is longer? Are all the children evenly spaced? Make a bulletin board where all the birds which eat fish are mounted on red paper placed in one column and all the birds which do not eat fish are placed on yellow paper in another column. Make sure the papers are evenly spaced as in the diagram. Which column is longer? Make a graph on cm graph paper where you color a red square in one column for the fish-eaters and a yellow square in the next column for the non-fish-eaters. What information does this give you? Make up other graphing problems for your classmates.

Evaluation: The birds which the students make and the completed diagrams and graphs should give you an indication of whether the students understand the concepts. The discussions preceding, during and after the students' work are important both to the students' understanding and the teachers' ability to judge the success of the activity.

Teacher Notes: This activity should be extended as children create their own birds and classification problems. Children may wish to extend this process to the study of other animals. Dinosaurs are also an interesting choice for young children. They might be classified according to meat-eaters and plant-eaters or according to those which fly and those which do not. Let the children suggest other problems.

Submitted by

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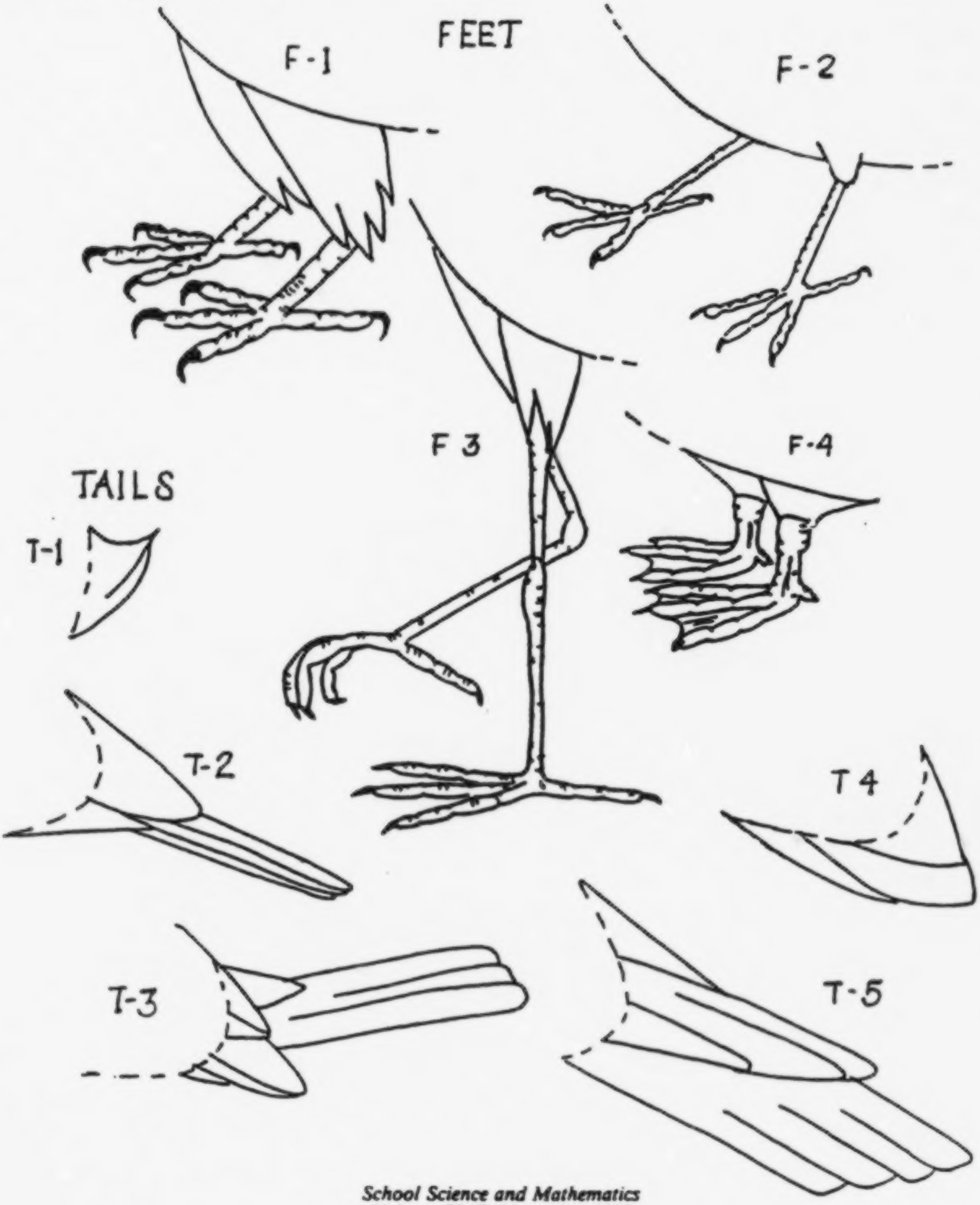
Bird Parts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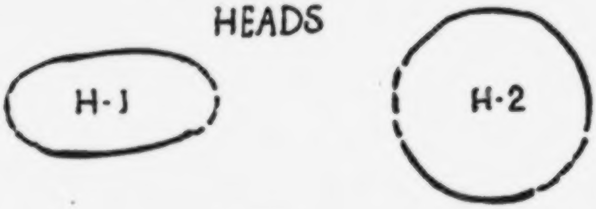
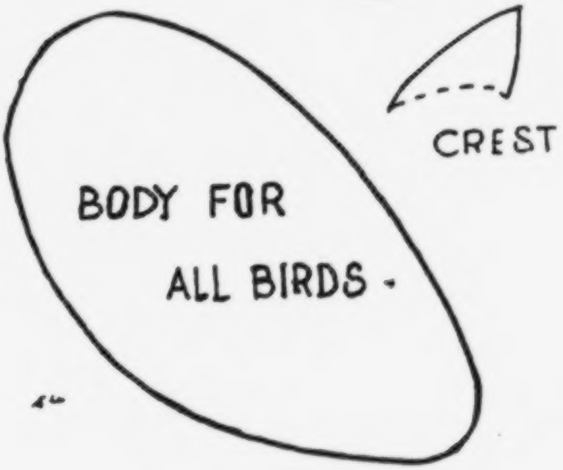
T-5

Bird Parts

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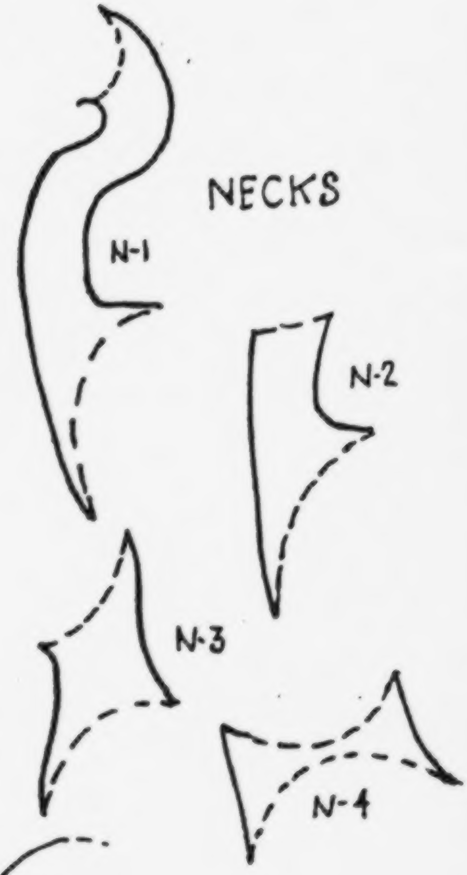
ALL BIRDS -
CREST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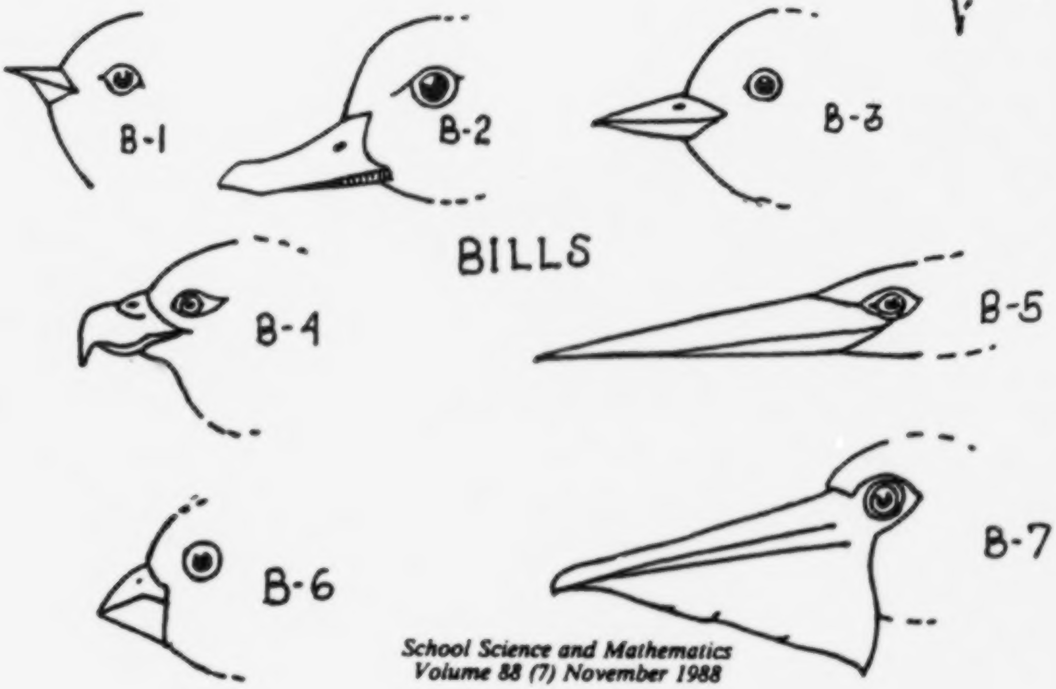
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BILLS
B-4
B-5
B-6
B-7

School Science and Mathematics
Volume 88 (7) November 1988

Letter received in reaction to
SSMILES #10
Feeding Pleasure Horses

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Your SSMILES #10, SSM Journal May 1988 is great! It is a good example of exactly what is needed for today's students, *any age, any grade level, any demographic or cultural environment*!

Does that surprise you? Do I hear some teacher say "But my students are in the inner city, culturally deprived, have never seen a *real* horse."? Aha! Just modify the format for a trucker who owns 5 trucks: 5 different makes—3 pickups corresponding to Fire, J. R., and Morgan, and 2 big trucks corresponding to Jasper and Smokey. The company operates 3 routes, one around town with light loads, another to a branch plant with moderate loads, and a third over the mountain with a heavy load (corresponding to light, moderate and heavy work). Trucks consume gas (hay), and oil (feed).

Or take sports. Football, basketball and baseball are one, two, three in work load, and in average player weight? Is there a protein-carbohydrate connection?

And at the college engineering level we have three power demand levels (work), plants in two states (weight), and interest on capital plus fuel costs (hay, feed).

At high school level consider car rental: a flat daily rate (hay), and a mileage charge (feed). You can drive all day (heavy work) . . . etc. And you can rent compact or full size.

With some classes we would start with the simplest case—one kitten, two activity levels (pet shop cage and your home) and one food. So be it!

Charlie Spiegel
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P.S. Please tell John Atherton I'd like to see a BASIC program for the simplest case.

SSMILES Department

Donna F. Berlin, Editor

Introducing the SSMILES Department

At a recent meeting of the Publications Committee of the School Science and Mathematics Association, it was decided to revise the SSMILES format to be a regular column, the SSMILES Department, in the *School Science and Mathematics* journal. For nearly two years, SSMILES (School Science and Mathematics Integrated Lessons) have been appearing in the journal as inserts. With the initiation of the new department, the SSMILES will continue to appear as a regular feature including grades pre-kindergarten through college rather than the previously limited focus upon early childhood and middle school grades.

In addition, the scope of the SSMILES Department will be expanded to include letters, comments, extensions to the SSMILES; ideas for future SSMILES; theoretical papers; bibliographies; reviews of the literature; reviews of programs, projects, and materials; and opportunities for collaborative research and development focusing upon the integration of science and mathematics education.

One of my goals as SSMILES Department Editor will be to encourage more classroom teachers to contribute their ideas and manuscripts to this new department. In order to support and encourage classroom teacher participation, the SSMILES reviewers will be asked to serve as resource persons and assist in writing where appropriate.

It is critical that we all contribute to this new department for it to be a success. Your contributions related to the integration of science and mathematics education are requested. Please send them to:

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can use to guide their investigation. Several excellent texts are available for this (DeVito & Krockover, 1980; DISD, 1977; Doherty & Evans, 1980). Finally, arrangements may have to be made for students to pursue their investigations beyond the time normally allocated for science or beyond the time in which they are in the gifted program. The nature of scientific investigations is such that students may require release time and assistance before and after school. Parents should be encouraged to assist their child at home by providing resources and materials. Parents may also need to help in getting their child to appropriate libraries since the needs of gifted children in a Stage III investigation quickly outstrip the resources available in most school libraries. Additionally, the teacher and parent may need to search out a mentor or individual (secondary teacher or college professor) with expertise in a specific area since the questions and need of the child involved in Stage III investigations is such that the teacher or parent's knowledge is not sufficient.

Conclusion

This model of science education for gifted students can provide the basis upon which students can develop their basic content knowledge, divergent thinking skills, creative problem solving techniques, and research skills. The ultimate goals are for the gifted student to become a producer of knowledge, both for himself and for those of us who might benefit from this knowledge. Finally, it is imperative that we develop within our gifted students the ability to conceptualize in science. The amassing of great quantities of scientific facts without attention to problem solving and creativity threatens to create technologists when there is the potential for scientists. A commitment must be made to help gifted students develop creative problem solving skills within their discipline. These creative problem solvers are then the goal of a truly differentiated science curriculum—scientists.

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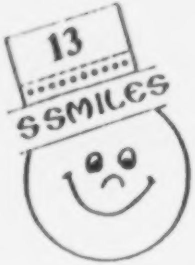

SSMILES

Donna Berlin, Editor

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Exploration of the Mean as a Balance Point
Grades 6-9

Mathematics Concepts/Skills	Science Concepts/Processes
mean	lever
distance	balance point
midpoint	center of gravity
	equilibrium
	mass
	force

Prerequisite Skills:

Understanding of number line, directed distances, arithmetic average, clockwise, counterclockwise

Prerequisite Activity:

Students should find the center of gravity of measuring sticks of varying length. (Teacher Note: The center of gravity will always be the midpoint of the measuring stick.)

Objective:

Students will develop the analogy between the mean and the fulcrum (balance point) of a lever.

Rationale:

The arithmetic average (mean) is a value representing information included in a set of data. It is often easier to deal with a single value that represents the information, instead of dealing with all of the numbers. It is relatively easy for students to compute the arithmetic average, however a conceptual understanding is difficult to develop. Providing a physical model of the mean can help students understand and appreciate important characteristics of this concept.

Researchers (Pollatsek, Lima, & Well 1981) have found that many students deal with the mean at a computational rather than a conceptual level, and knowledge of the computational rule does not imply an understanding of the basic concept. An analogy involving physical or dynamic images can develop conceptual understanding. The lever has many applications in everyday life and can be used to give physical meaning to the mean. The balance point of a lever (fulcrum) can be related to the abstract concept of the mean.

For this lesson, the midpoint of the measuring stick (center of gravity), the balance point of the stick (fulcrum) and the arithmetic mean are assumed to be the same point. For example, on a meter stick the 50cm mark identifies this point. The midpoint of the stick has been selected as the fulcrum or mean so that the mass of the stick will not influence the location of the balance point. A more comprehensive representation of this physical model which takes into consideration the mass of the stick may be appropriate at higher grade levels.

Content Background:

The mean ($\bar{X}$) is the sum of a set of numbers ($X_1, X_2, X_3, \dots, X_n$) divided by the total number of values (n), that is:

$$\bar{X} = (X_1 + X_2 + X_3 + \dots + X_n)/n$$

The mean can be related to the balance point (fulcrum) of a lever. The fulcrum is the point at which the clockwise force (moment of force) is equal to the counterclockwise force (moment of force). This relationship can be shown by using a meter stick supported at the midpoint. Weights can be placed at different points along the meter stick in order to balance the stick.

The distance of the weight to the right of the fulcrum times the mass of the weight (magnitude) determines the force trying to rotate the meter stick in a clockwise direction. This product (mass x distance) is the clockwise moment of force. The counterclockwise moment of force can be represented as the distance of a weight to the left of the fulcrum times the mass of the weight (magnitude) and determines the force trying to rotate the meter stick in a counterclockwise direction. A clockwise moment of force can be represented as a positive (+) value and the counterclockwise moment of force as a negative (−) value.

Lesson Outline:

Time: Two or three 40 minute sessions

Material/Supplies per student pair:

Measuring sticks	Assorted lengths: 20cm, 40cm, 50cm, 100cm)
Meter stick	Notched at 10cm markings along top edge and at 50cm mark on bottom edge (use small triangular file to make notches)
6 - 8 large paper clips	Opened up to form a large "S". One end of the paper clip can be slipped over the meter stick and the other end will support the weights.
6 - 8 washers	Approximately 4cm in diameter.
2 blocks	To support stick above table high enough to hang washers under the stick on the paper clips.
String	To support meter stick. Tie a loop in one end to slip over the meter stick and attach other end to overhead support.

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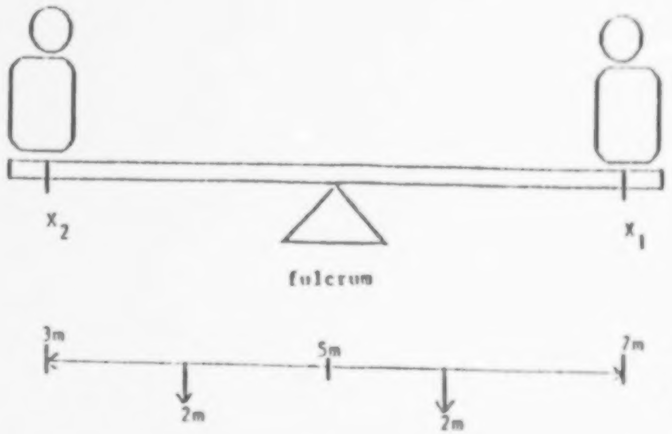
Procedure:

1. Begin with a discussion of a familiar lever, the see-saw. If two children of equal mass want to balance on a see-saw, they have to sit symmetrically with respect to the position where the see-saw rotates. They must sit at the same distance from the point of balance; one to the right, the other to the left (Figure 1.). The point of balance is the fulcrum and can be found by computing the average of the two values X_1 and X_2 on the number line. For example, 5m is the midpoint between 3m and 7m on the number line and is calculated by (3m + 7m)/2 = 5m. The two children are both 2m from the fulcrum.

Figure 1.



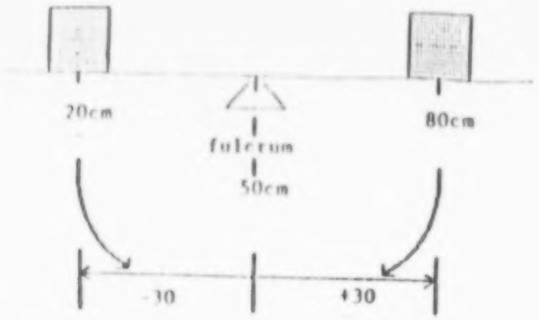
2. Give each pair of students a meter stick with blocks or books to support each end. Place the loop, on one end of a length of string, over the meter stick at the 50cm notch. Attach the other end of the string to the overhead support.

3. Give each pair of students two washers of equal mass and two large paper clips of the same size and ask them to hang the washers on the meter stick so that the meter stick will balance when the end supports are removed. The students should record the number (10cm, 20cm, . . . , 100 cm) corresponding to the position for which the stick balanced (or nearly balanced). The students should be encouraged to find more than one combination to balance the stick. What patterns result? How would you describe the conditions under which the stick balanced?

(Teacher Note: When the stick balances the total clockwise force should be the same as the total counterclockwise force. Determine the distance that the washer on the right side is from the fulcrum. Determine the distance that the washer on the left side is from the fulcrum. The distances should be the same.)

4. Distribute the student worksheet so students can record their data. For example when using two washers (Figure 2), the following data might result.

Figure 2.



Number of Washers	Washer Position	Distance from Fulcrum	Force
1	80cm	80cm − 50cm = + 30cm	clockwise force (+) washer to the right Total + 30(cm)(washer)
1	20cm	20cm − 50cm = − 30cm	counterclockwise force (−) washer to the left Total = − 30(cm)(washer)

The clockwise force (+ 30) balances the counterclockwise force (− 30).

5. Have the students compute the means for the pairs of distances they used to balance the meter stick. To compute the mean, add the scores together and divide by the total number of scores. Compare the results of these calculations to the results of your experiments. For instance, if you apply this method of calculation to this example:

$$\text{Sum} = 20\text{cm} + 80\text{cm} = 100\text{cm} \qquad \text{Mean} = 100\text{cm}/2 = 50\text{cm}$$

This is the mean score and is also the balance point or fulcrum of the meter stick. It is the point at which the clockwise moment of force is equal to the counterclockwise moment of force and the system is in a state of equilibrium.

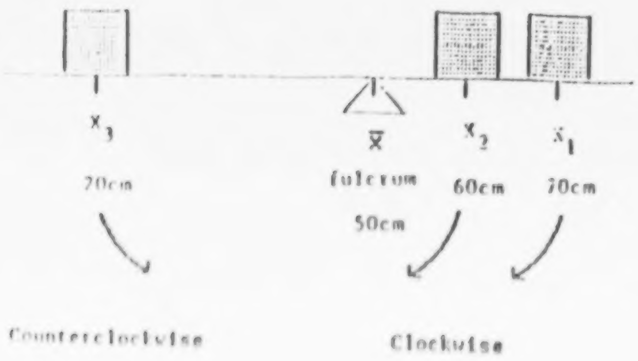
6. Give each pair of students three washers, four washers, and so on, and have them repeat steps 3, 4, and 5.

(Teacher Note: When the stick balances the total clockwise force should be the same as the total counterclockwise force. Determine the distance that each washer on the right side is from the fulcrum and sum these. Determine the distance that each washer on the left side is from the fulcrum and sum these. The sums should be the same.)

For more advanced students, the following mathematical representation may be appropriate. If we work with three unit weights, the rotating effects with respect to $\bar{X}$ are given by the arm lengths $X_1 - \bar{X}$, $X_2 - \bar{X}$, and $X_3 - \bar{X}$. When the sum of the rotating effects is zero, that is if:

$$(X_1 - \bar{X}) + (X_2 - \bar{X}) + (X_3 - \bar{X}) = 0 \qquad \text{(See Figure 3.)}$$

Figure 3.



This indicates that the rotating effects of the weights at X_1, X_2, and X_3 cancel each other. Thus, if we hold the lever at $\bar{X}$ the system is in equilibrium. For example, the numbers 20, 60, and 70 have a mean $\bar{X} = 50$. The weights at 60 and 70 tend to rotate the lever clockwise $(60 - 50) > 0$, $70 - 50 > 0)$, while the weight at 20 tends to rotate the system counterclockwise $(20 - 50 < 0)$.

Since $(60 - 50) + (70 - 50) + (20 - 50) = 0$, the system is in equilibrium (Figure 3).

Evaluation:

The teacher should observe the students during the activity to check on the values they obtain for the positions of the weights when the stick is balanced. The number of alternative combinations should be noted. The Figures 1 — 3. can be reproduced, omitting some of the numbers, arrows, fulcrum, and other elements. The students can be evaluated on their ability to correctly supply the missing information.

Teacher Notes:

1. Strauss and Bichler (1988) list several properties of the mean that are important to the understanding of the concept. The following chart compares properties of the mean to properties of the fulcrum.

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Analogous Properties

Mean	Fulcrum
a. located between extreme scores	a. located between extreme weights
b. sum of score deviations from the mean = 0	b. the sum of clockwise and counterclockwise forces = 0
c. value of the mean will be changed when scores not equal to the mean are added	c. balance point will be changed by adding weights to left or right of fulcrum
d. mean does not have to equal one of the scores	d. fulcrum does not have to be at one of the weights
e. mean is representative of the group of scores	e. fulcrum is the center of equilibrium for the weights

Readers interested in learning more about this topic are referred to Polya (1977) and Schiffer (1984).

2. Several other concrete models can be used to develop the concept of the mean (Reys, Suydam, & Lindquist, 1984). For example, children can use adding machine tape to represent scores, where the length of the strip is determined by the score. To show the average (mean) of two scores, tape the two strips of paper together and then fold the resulting strip in half. Students could also use columns of blocks or books and then ask students to "even out" the blocks as much as possible.

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STUDENT WORKSHEET

Number of Washers	Washer Position	Distance from Fulcrum	Force
		clockwise forces (+)	
1	____ cm	____ cm − 50cm = + ____ cm	washer to right
1	____ cm	____ cm − 50cm = + ____ cm	washer to right
1	____ cm	____ cm − 50cm = + ____ cm	washer to right
1	____ cm	____ cm − 50cm = + ____ cm	washer to right
		Total = + ____ (cm)(washers)	
		counterclockwise forces (−)	
1	____ cm	____ cm − 50cm = −____ cm	washer to left
1	____ cm	____ cm − 50cm = −____ cm	washer to left
1	____ cm	____ cm − 50cm = −____ cm	washer to left
1	____ cm	____ cm − 50cm = −____ cm	washer to left
		Total = − ____ (cm)(washers)	

1. The total clockwise force (+ ____), balances the total counterclockwise force (− ____).

2. Compute the mean of the washer positions on the meter stick.
Mean = (Sum of Washer Positions)/Number of Washers
Mean = (____________ cm)/(________ Washers)
Mean = (______ cm)

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SSMILES

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Fulcrum and Mean: Concepts of Balance
High School/College

Mathematics Concepts/Skills	Science Concepts/Processes
mean	center of gravity
standard unit	fulcrum
frequency distribution	moments of force
deviation score	standard mass unit

Prerequisite Skills:
Understanding of a lever system, computation of the mean of a distribution of scores, and the ability to represent a group of scores as a frequency distribution.

Prerequisite Activities:
Completion of SSMILES 13: Exploration of the Mean as a Balance Point (Penafiel & White, 1989)

Objective:
Identify the correspondence between the elements of a lever system and the properties of a frequency distribution.

Rationale:
SSMILES activity #13 (Penafiel & White, 1989) relates the fulcrum of a lever system and the mean of a distribution of scores. To simplify the physical model, the position of the fulcrum of the lever system was restricted to the center of gravity of a meter stick (the 50 centimeter mark). This, in effect, eliminated the need to consider the influence of the weight of the meter stick on the lever system. Assuming that the meter stick is uniform along its length, the equal portions of the meter stick to the left and to the right of the fulcrum would have the same clockwise and counterclockwise forces influencing the

balance. In this extension we will explore the relationship between a lever system and the mean of a distribution for a system where the fulcrum is allowed to vary in position along the length of the lever.

Content Background:

To adjust for the influence of the different weights of the stick to the left and right of the fulcrum, we will use the following concepts: center of gravity, standard mass unit, frequency distribution, and deviation scores from the mean.

Center of Gravity is the point for a physical object at which the forces of gravity appear to be centered. If the object is supported at this point it balances.

Fulcrum is the point of a lever system which separates the clockwise and counterclockwise forces. It is the point around which a lever turns.

Standard Mass Unit is a mass we select as the unit of comparison and is descriptive of the amount of matter of an object. We measure mass by weighing the object. We have selected the mass of 1-washer as our standard unit for this activity.

Frequency Distribution is a histogram in which the scores and the number of occurrences are represented. It is a tally of scores arranged from the lowest of the scores to the highest. Each score represents 1 unit (person) and will correspond to the unit weight ("washer") in the lever system. The size (magnitude) of the score in a frequency distribution corresponds to the centimeter mark at which the washer is located.

Deviation Score is the difference between a score and the mean of scores for a frequency distribution. When a score is larger than the mean the difference is positive and when the score is smaller the difference is negative. These deviation scores correspond to the clockwise and counterclockwise forces in a lever system.

Lesson Outline:

Time: Two, 55-minute sessions

Materials/Supplies Per Student Pairs:

Meter stick

(It is recommended that triangular notches be made along both edges of the meter stick at the 10 centimeter markings. This can easily be done by using a small triangular file.)

6 - 8 large paper clips opened at both ends so that they can be suspended from the meter stick

6 - 8 large washers about 4 centimeters in diameter

2 - supports for the meter stick

(These supports should be high enough to allow the weights to be added or removed easily.)

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String

(This is to be used to support the meter stick from a ring or any other overhead support).

Platform balance

Procedure:

The following procedures are designed to illustrate the correspondence between the fulcrum of a lever system and the mean of a frequency distribution. These activities can be done by groups of 2-4 students or perhaps in a group demonstration format.

1. Support a meter stick from above using a piece of string. The string should be loose enough on the stick so it can be easily moved from one support point to the next.
2. Determine the mass (weight) of the meter stick by weighing it with a platform balance.

   ______________ gms
3. Determine the average mass of the washers (MW) by weighing 5 washers then dividing that weight by 5.

$$MW = \frac{\text{Mass of five washers (\_\_\_\_\_\_ gms)}}{\text{Number of washers (\_\_\_\_\_\_)}} = \_\_\_\_\_\_\_\_ \text{gms}$$

4. Hang four of the washers on the meter stick, one at each of the following locations: 80cm, 70cm, 60cm, 30cm
5. Determine and record the centimeter position of the overhead support string at which the stick and the washer system balances. This is the fulcrum position (FP).

   FP = ______________ cm
6. Determine the center of gravity for the arm of the stick to the right of the fulcrum. (RCG)

$$RCG = FP + \frac{\text{(100cm - fulcrum position in cm)}}{2} = \_\_\_\_\_\_ \text{cm}$$

7. Determine the center of gravity for the arm of the stick to the left of the fulcrum. (LCG)

$$LCG = \frac{\text{(fulcrum position in cm)}}{2} = \_\_\_\_\_\_ \text{cm}$$

8. The students should find the mass of the arm of the meter stick to the right of the fulcrum (MR).

$$MR = \frac{\text{(100cm - fulcrum position cm)}}{\text{100cm}} \times \text{(mass of stick in gms)} = \_\_\_\_\_\_ \text{gms}$$

9. The students should find the mass of the arm of the meter stick to the left of the fulcrum (ML).

$$ML = \frac{\text{(fulcrum position cm)}}{\text{100cm}} \times \text{(mass of stick in gms)} = \_\_\_\_\_\_ \text{gms}$$

10. Calculate the clockwise forces acting on the lever system by completing the following data table:

10.1. Washer #1:
  a. Fulcrum position (FP) ________ cm
  b. Washer #1 position (WP#1) ________ cm
  c. Distance from fulcrum DF#1 = (WP#1 - FP) + ________ cm
  d. Mass (MW) ________ gms
  e. Force F#1 = (MW × DF#1) + ________ (gms)(cm)

10.2. Washer #2:
  a. Fulcrum position (FP) ________ cm
  b. Washer #2 position (WP#2) ________ cm
  c. Distance from fulcrum DF#2 = (WP#2 - FP) + ________ cm
  d. Mass (MW) ________ gms
  e. Force F#2 = (MW × DF#2) + ________ (gms)(cm)

10.3. Meter stick (right arm):
  a. Fulcrum position (FP) ________ cm
  b. Right side center of gravity position (RCG) ________ cm
  c. Distance of RCG from fulcrum DRCG = (RCG - FP) + ________ cm
  d. Mass (MR) ________ gms
  e. Force FR = (MR × DRCG) + ________ (gms)(cm)

Total clockwise force = 10.1e + 10.2e + 10.3e = + ________ (gms)(cm)

11. Calculate the counterclockwise forces acting on the lever by completing the following data table:

11.1. Washer #3:
  a. Fulcrum position (FP) ________ cm
  b. Washer #3 position (WP#3) ________ cm
  c. Distance from fulcrum DF#3 = (WP#3 - FP) - ________ cm
  d. Mass (MW) ________ gms
  e. Force F#3 = (MW × DF#3) - ________ (gms)(cm)

11.2. Washer #4:
  a. Fulcrum position (FP) ________ cm
  b. Washer #4 position (WP#4) ________ cm
  c. Distance from fulcrum DF#4 = (WP#4 - FP) - ________ cm
  d. Mass (MW) ________ gms
  e. Force F#4 = (MW × DF#4) - ________ (gms)(cm)

11.3. Meter stick (left arm):
  a. Fulcrum position (FP) ________ cm
  b. Left side center of gravity position (LCG) ________ cm

  c. Distance of LCG from fulcrum DLCG = (LCG - FP) - ________ cm
  d. Mass (ML) ________ gms
  e. Force FL = (ML × DLCG) - ________ (gms)(cm)

Total counterclockwise force = 11.1e + 11.2e + 11.3e = - ________ (gms)(cm)

12. Compare the total clockwise and counterclockwise forces. (Teacher Note: The total clockwise and counterclockwise forces should be nearly equal.)

To explore the relationship of the fulcrum of a lever and the mean of a group of numbers we must first express the masses involved in the balancing of the lever in a standard unit. We will do this by converting all masses into "washers". The weights on the lever are already in "washers" because they were in fact washers. The mass of the stick was in grams so we must convert the masses of the arms of the meter stick to the right and left of the fulcrum into "washer" units.

13. Determine the mass of the right arm of the meter stick in "washer" units (MRW). To do this, the mass of the right arm of the stick (MR) should be divided by the average washer mass (MW).

MRW = MR/MW = ________ "washers"

14. Determine the mass of the left arm of the meter stick in "washer" units (MLW). To do this, the mass of the left arm of the stick (ML) should be divided by the average washer mass (MW).

MLW = ML/MW = ________ "washers"

The numbers for a frequency distribution that correspond to the lever analogy are the centimeter locations of each "washer" mass. This would include one number (score) for each washer. The washer at the 80 centimeter mark would result in 80 as one of the scores, the washer at 70 centimeters is equivalent to a score of 70, the washer at 60 centimeters is a score of 60, and the washer at 30 centimeters is a score of 30. If two washers were at the same centimeter mark then the score for that centimeter mark would be included twice.

The meter stick mass has been converted into our standard mass unit, the "washer". The number of washers needed to represent the mass of each arm of the meter stick (right and left of the fulcrum) determine how many times the scores representing the respective centers of gravity must be included in the distribution of scores. See Teacher Note #1 for an example of this computation.

15. Compare the mean of these scores with the location of the fulcrum. (Teacher Note: These values should be nearly the same).

16. Describe the relationship between the position of the fulcrum and the computed value of the arithmetic mean. What variables influence the rotation of the lever or the clockwise and counterclockwise moments of force? See Teacher Note #2 for an example of calculations for a lever system different than the laboratory setup described in steps 2-5.

Evaluation:

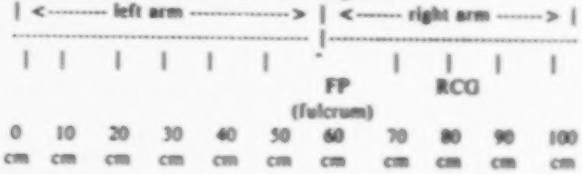
Check the students calculations for the balance of forces for the lever and for the computation of the mean. Provide the students with additional lever systems and have them determine (experimentally) the location of the fulcrum and verify this by computation of the clockwise forces, the counterclockwise forces, and the mean.

Teacher Notes:

Note #1: When the weight of the right and left arms of the lever are taken into consideration it is necessary to determine two factors: (1) the mass of each arm of the lever in standard mass units and (2) the location of the center of gravity of the mass of each arm of the lever.
Consider the situation illustrated by Figure 1.

Figure 1.

Given: (1) a meter stick lever with the fulcrum at the 60 centimeter mark,
(2) the arm of the meter stick to the right of the fulcrum has a mass of 40 grams, and
(3) the standard mass unit (washer) is 20 grams.


| <--------- left arm ----------------> | <------- right arm -------> |
FP
(fulcrum)
RCG
0 cm
10 cm
20 cm
30 cm
40 cm
50 cm
60 cm
70 cm
80 cm
90 cm
100 cm

The calculations follow:

Factor (1). Mass of the right arm of the lever in washers (MRW). (See step 13.)

MR = 40 gms
MW = 20 gms/washer

$$\text{MRW} = \frac{40 \text{ gms}}{20 \text{ gms/washer}} = 2 \text{ washers}$$

Factor (2). Center of gravity of right arm (RCG). (See step 6.)

$$\text{RCG} = 60 + \frac{100 \text{ cm} - 60 \text{ cm}}{2} = 60 + 20 = 80 \text{ cm}$$

The mass of the right arm of the meter stick, in standard mass units turns out to be 2 washers and the center of gravity where the mass exerts a clockwise force on the meter stick is at the 80 centimeter mark. The standard mass units and the center of gravity of the left arm of the lever would be computed in a similar fashion.

Note #2: The following situation is an example illustrating a lever system/frequency distribution. The situation is diagramed in Figure 2 and the appropriate calculations are included to demonstrate the correspondence between the concepts of the fulcrum and the mean.

Situation. A meter stick which weighs 200 grams is used for a lever. The fulcrum is located at the 60 centimeter mark and washers, each having a mass of 20 grams, are placed as follows:

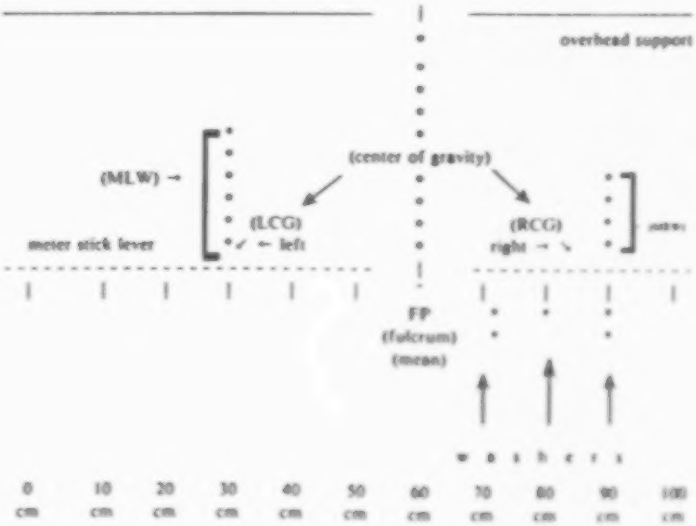
2 washers at 70cm
1 washer at 80cm
2 washers at 90cm

Question: Will the meter stick (lever) balance with the fulcrum at the 60 centimeter mark? Support your conclusion using the two methods listed below:

1. the properties of a lever system
2. the properties of the mean of a frequency distribution

The verification of the 60 centimeter position as the fulcrum and the mean follows Figure 2.

Figure 2.



Calculations to verify fulcrum position:

Clockwise forces = weights × distances from fulcrum summed

1 washer × 70cm - 60cm = + 10 washer - cm
1 washer × 70cm - 60cm = + 10 washer - cm
1 washer × 80cm - 60cm = + 20 washer - cm
1 washer × 80cm - 60cm = + 20 washer - cm
1 washer × 80cm - 60cm = + 20 washer - cm
1 washer × 80cm - 60cm = + 20 washer - cm
1 washer × 80cm - 60cm = + 20 washer - cm
1 washer × 90cm - 60cm = + 30 washer - cm
1 washer × 90cm - 60cm = + 30 washer - cm
Clockwise Force = + 180 washer - cm

Counterclockwise forces = weights × distances from fulcrum summed
1 washer × 30cm - 60cm = - 30 washer - cm
1 washer × 30cm - 60cm = - 30 washer - cm
1 washer × 30cm - 60cm = - 30 washer - cm
1 washer × 30cm - 60cm = - 30 washer - cm
1 washer × 30cm - 60cm = - 30 washer - cm
1 washer × 30cm - 60cm = - 30 washer - cm
Counterclockwise Force = - 180 washer - cm

Calculation of the mean:

Sum of Scores = 30 + 30 + 30 + 30 + 30 + 30 + 70 + 70 + 80 + 80 + 80 + 80 + 80 + 90 + 90 = 900

Mean = Sum of Scores/Number of Scores = 900/15 = 60

References:

Penafiel, A. F., & White, A. L. (1989). SSMILES: Exploration of the mean as a balance point. *School Science and Mathematics*, *89*(3), 251-258.

SSMILES

Donna F. Berlin, Editor

This month's SSMILES is an activity for grades K-3 called "Let's Slide Down the Slope" which is one of many activities that can be found in the School Science and Mathematics Association monograph *Classroom Activities Series #2*. This monograph is written by Walter A. Farmer, Professor of Science Education, and Margaret A. Farrell, Professor of Mathematics Education, at the State University of New York at Albany. It is the product of the collaborative effort of the mathematics and science education faculty at the State University of New York at Albany and representatives of eight school districts in the Capital District Area in a project funded by the New York State Education Department.

The monograph is a collection of activities designed to teach math/science concepts and meet the following criteria: (1) combine important mathematics and science learnings in a single lesson; (2) have been tried out by classroom teachers and elementary school children; (3) involve "hands-on" activity; and (4) use readily available, everyday materials. The activities are generally identified for grades kindergarten through third and fourth through sixth but can be adapted to meet the needs of other grade levels.

The monograph will be published in 1989 and can be ordered from: Executive Office, School Science and Mathematics Association, Bowling Green State University, 126 Life Science Building, Bowling Green, Ohio 43403-0256, telephone (419) 372-7393.

Let's Slide Down the Slope

Procedure: Set up demonstration slide high enough so that all of the children can see it. Ask children to imagine that they are walking up a playground slide. If the slide is raised (demonstrate), will the child wearing dress shoes begin to slide backward before the child with sneakers on? Why? Tell the children that they're going to see what properties affect sliding. Ask the children to make observations of the objects (shape, size, texture). Demonstrate how you will raise the plank until an object placed on it slides. Point to the location on the vertical meter stick which indicates the height of the plank when the sliding starts.

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Volume 89 (5) May/June 1989

With a group of objects, ask students to predict those which are likely to slide first, last. Try one or two objects and discuss the result. Continue the trials and ask a student to mark (with sticky tape, stickers, . . .) the vertical meter stick at the point where the plank is when the object first begins to move. Have another student read the place on the meter stick which has been marked. (With young children, who would have trouble reading the meter stick, color code each object and use a sticker of that color to mark the meter stick. Then compare the sliding properties of a group of objects by looking at the colored sticker which is highest, lowest.). Record the data. Use student shoes with different soles (leather versus sponge, different patterns on sneakers, . . .).

Ask questions such as "What are the properties (size, shape, texture) of the object? Which will move first, last? Why is it important to measure height? Why is it important to record the results? Does size make a difference? When? Why? Does shape make a difference? Which? Why? Do smooth objects move before rough objects? Do balls move before objects with flat sides? Are you sure?" Discuss. Graph the data and talk about the graph.

Materials: A plank about 6 inches wide and 3 to 4 feet long; a meter stick held vertical by a clamp; a collection of objects of various sizes and shapes, such as round and hexagonal pencils, balls of different sizes, blocks of wood wrapped in sandpaper, aluminum foil, wax paper, etc., and students' shoes with different sole types; sticky tape or stickers to mark the meter stick.

Key Concepts, Skills, and Processes

Mathematics: Concepts of height, angle, slope, and shape concepts (round, flat, smooth, edges, sphere, cube); processes of reading meter stick, observing, collecting, recording and analyzing data.

Science: All of the processes above and also predicting; concepts of inclined plane, work, gravity and friction.

Background: An inclined plane is often used to move heavy loads up or down with less energy being expended. The decrease in energy expended is compensated for by the additional diagonal distance the load must travel. The factors which affect friction can be explored as children observe what slides easily and how the angle of the plank affects sliding ("dilutes" the effect of gravity).

Extensions: Ask children to try to think of places where they've seen an inclined plane in use, other than in the playground. Ask them to look for pictures of inclined planes in use. Discuss ramps for wheelchairs, slides from moving vans to the street, . . .

SSMILES

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Heart Throbs

Grades 5-9

Mathematics Concepts/Skills
statistical averages: mean, mode,
bar or linear graphs,
interpretation of graphs and data

Science Concepts/Processes
heart rate, data collection,
observing, comparing,
hypothesizing, inferring, predicting

Objectives:

1. By exploring the effect of various activities on their hearts, the students will make predictions concerning their own pulse rate for each activity.
2. By looking at group and class averages of heart rates during certain activities, students will investigate the relationship of physical conditioning to heart rate and the recovery rate associated with the activity.

Rationale:

Interrelationship of Skills and Concepts: The opportunity to collect data, make conjectures, and test those conjectures is the heart of investigations in mathematics and science. The use of personal data is especially motivating for students. The data when put in mathematical representations such as tables, graphs, and averages provide the students with the opportunity to discover and interpret the relationship between mathematical representations and the scientific correlation between physical condition and heart rate when doing everyday activities.

Content Background: For extending the activity from personal data to class data, students will need to be able to find the mean by using a calculator and the mode by observing a bar or line graph. Students will also need to be able to make comparisons between physically active students (perhaps those participating in school sports or other equally strenuous activities such as dancing, aerobics, aquatics, bicycling, martial arts, etc.) and those who are not. An understanding of ratio would be helpful to this comparison.

The heart rate of a well-conditioned person during an activity and shortly afterwards is significantly different from the heart rate of a person who is not well-conditioned. For example, a well-conditioned person may need to do a more strenuous task to raise his/her heart rate to 150 beats per minute (bpm) compared to a less-conditioned person. In addition, the recovery heart rate shortly after an activity for a well-conditioned person will aproximate his/her inactive heart rate while the recovery rate of a less-conditioned person will remain higher for a longer period of time.

Lesson Outline:

Time: Two or three 30-45 minute periods
Materials/Supplies:
  Stop watch or clock with second hand
  Copies of Student Data Collection Sheets
  Calculators
  Graph paper and different color marking pens
Preparation: Students need to be able to take their own pulse. Usually the easiest place to feel one's pulse is in the neck region by placing the forefinger on the carotid artery while the head is tilted back. There are other alternatives such as commercial or teacher-made stethoscopes or finding a pulse in the wrist area using the forefinger.

Procedure:

Place the students in cooperative groups of four or five. The students can begin collecting data on their heart rates for each of the items on the student activity sheet. Pulse rates can be taken for 15 seconds and then multiplied by 4 to get beats per minute (bpm). All entries should be in bpm. For each entry, the pulse should be taken twice, once by the student himself/herself, and once by another person in the group. An average between the two could be used if there are discrepancies. Students must enter a conjecture where asked before actually doing the activity and finding a pulse in bpm. The following are suggested tasks to be completed:

1. Students carry out the experiments and record their data on the student activity sheets.
2. Let the class determine which students in the class are involved in regular physical activity.
   a. Have the students predict how the average inactive, active, and recovery pulse rates of the physically active will compare to those of the rest of the class.
   b. Assign averaging responsibilities to different groups. The groups are to calculate the average in each category (inactive, active, and recovery) for the students regularly participating in physical activity and those who do not.
   c. What conclusions, if any, can be made on conditioning and the three heart rate categories? How did the actual results compare to student predictions?

3. Have each group complete the following whole class statistics.
   a. Calculate the class heart rate mean and mode for each category.
   b. Create a frequency histogram or bar graph for each category. Use ranges 56-60, 61-65, 66-70, etc., for the inactive pulse rate. Use appropriate ranges for the other two categories.
4. As an extension, have students create hypotheses that they would like to test as a project (e.g., predict how teacher/parent heart rates would compare within each category).

Evaluation:

The student predictions and data from the activity sheets will demonstrate attainment of the first objective. The quality of the group graphs and hypotheses should give an indication of whether students understand the underlying concepts concerning conditioning, activity, and heart rate.

Teacher Notes:

Note #1: The teacher needs to identify students with medical problems that should not physically participate in the "active pulse" data collection procedures. They can participate in all small group and class discussions and in the collection (for other students), recording, calculating, organizing, and graphing of data.

Note #2: In order to draw the bar graphs (Item 7 on the student data collection sheet), students may need assistance in determining appropriate ranges for the inactive, active, and recovery pulse rates for each activity.

Extensions:

1. The students can use a calculator to find the class mean inactive, active, and recovery pulse rate for each of the activities in Item 6 on the Student Data Collection Sheet. The students can make bar graphs (similar to Item 7) to display this data.
2. The students can make bar graphs comparing their inactive, active, and recovery pulse rate (Item 7) to the class mean inactive, active, and recovery pulse rate (Extension 1) for each of the activities in Item 6.
3. The students can use a calculator to find the mean inactive, active, and recovery pulse rate for those students who regularly participate in physical activity and those students who do not for each of the activities in Item 6. Students can make bar graphs (similar to Extension 2) to display this data.
4. Related instructional resource:

   Science Tool Kit Module 3: Body Lab
   Broderbund Software, Inc.
   San Rafael, California

   This software program can be used to collect and display data related to heart rate. It includes an On Screen Heart Rate Meter which measures and displays heart rate during a variety of activities and a Heart Rate Plotter which prints the data in graphical form.

References

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Cooper, K. (1970). *The New Aerobics*. New York: Bantam.

Edlin, G., & Golanty, E. (1988). *Health & Wellness* (3rd ed.). Boston, MA: Jones and Bartlett.

Stronck, David (Ed.). (1983). *Understanding the Healthy Body*. Columbus: SMEAC Information Reference Center, The Ohio State University.

Student Data Collection Sheet
Heart Throbs

1. a. Guess how many times your heart beats in one minute._______ bpm (beats per minute)
   b. Now take your pulse for 15 seconds. Multiply the number of beats times 4 to get beats per minute. Record it in the inactive column of the table under self.

Inactive Pulse		Active Pulse		Recovery Pulse	
Self	Partner	Self	Partner	Self	Partner

Average: _______ bpm _______ bpm _______ bpm

   c. Have your partner take your pulse and record it in the inactive column under partner. If they are slightly different, take the average of the two and record. If they are very different, you and your partner should take your pulse over again.
2. a. Predict what your pulse rate would be after running for two minutes._______ bpm
   b. Run in place for two minutes.
   c. Record your pulse in the active column under self.
   d. Have a partner also take your pulse and record in the active column.
   e. Average the two rates if slightly different.
3. Rest five minutes.
4. a. Predict your pulse rate after resting._______ bpm
   b. Have you and someone in your group take your pulse and record both readings in the recovery column.
   c. Compare your average bpm under the active and recovery columns with other students in your group.
5. Use your calculator and your average bpm in the inactive column to find:
   a. How many times your heart beats in one class period._______
   b. How many times your heart beats in one 24-hour day._______

c. How many times your heart has beaten since you were born.________

d. How many days from now until your heart beats 1,000,000 times._______

6. Make a prediction of what your pulse rate would be during each activity and during the recovery phase. Then do the activity and take your pulse. Rest for five minutes and take a recovery pulse.

Activity	Predicted Active Pulse	Active Pulse	Predicted Recovery Pulse	Recovery Pulse
Clumbing up and down steps				
Walking for 2 minutes				
Taking a 2-minute timed math test				

7. Make a bar graph for each activity in Item 6 comparing your inactive pulse (which was determined in Item 1), active pulse, and recovery pulse. (Note: You may draw one bar graph using different colors to represent each activity or you can draw three separate bar graphs, one for each activity.)

SSMILES

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Food Labels
Grades 5-9

Mathematics Concepts/Skills

equations with conversion factors/constants, percent, bar graphs, scaling, interpretation of data and graphs, serial order

Science Concepts/Processes

nutrition, calories, fats, data collection and organization, comparison, classification, interpretation

Objectives:

1. By reading the labels on food packages, the students will be able to calculate the percentage of calories per serving that come from fats.
2. By comparing the percentages of calories from fats in various foods with the recommendations for an appropriate diet, the students will be able to classify foods according to their nutritional value.
3. Students will be able to use a numerical constant in a calculation.
4. Students will be able to use percent to express parts per one hundred.
5. Students will be able to construct bar graphs.

Rationale:

Interrelationship of Skills and Concepts: In this activity, students will work with data provided by the labels on containers of food. The use of food labels is highly motivating because students are interested in selecting foods, improving their diets, and dealing with real data. The students will make choices by interpreting mathematical data according to recommendations of scientists. The process involves equations with conversion factors/constants, graphs, and classification.

Content Background: Most American youngsters recognize that they eat too many junk foods. Unfortunately, the term "junk food" is vague because most Americans are unable to define the appropriate percentages of calories from each nutrient that should be in their diet. Textbooks rarely give U.S. government's recommended standards. The discussion of good diets in most schools usually begins and ends with the broad assertion that the diet is adequate when it contains some servings from each of the following food groups: milk-cheese group, meat-poultry-fish-bean group, vegetable-fruit group, and bread-cereal group. Using the four food groups as a guide for diet promotes the overconsumption of animal fats from the milk group and the meat group and this is a nutritional mistake.

The U.S. government recommends that the average American should greatly reduce the consumption of fat. The current average amount of fat in the diet provides 42% of the calories. Fat should not contribute more than 30% of the calories in the diet. Americans would probably benefit from much less than the recommended 30%. Americans also tend to consume far too much refined and processed sugar, e.g., sucrose. The average amount of refined sugar in the diet provides 18% of the calories. Refined sugar should not give more than 10%. On the other hand, the consumption of starches and naturally occurring sugars in fresh fruit, e.g., fructose, should be increased from the current level of 18% of the calories to 48% of the calories.

Lesson Outline:

Time: Three or four 30-45 minute periods
Materials/Supplies:

- Food containers or the parts of containers that give the list of ingredients and the nutrition information per serving
- Copies of Food Label Chart and Worksheet for Nacho Cheese Soup/Dip (one per student)
- Copies of Food Label Chart (one for each food label or approximately 12 per student)
- Copies of Student Worksheet (one per student)
- 100 centimeter cubes or squares for each student or group of students (see Teacher Note #5).
- Graph paper (1/2 cm squares)
- Different colored marking pens
- Calculators

Preparation: Collect enough food labels to provide each student with at least 12 different food labels. In many schools, the students will cooperate by bringing labels from their homes. At least a week is needed for the collection of labels because they are usually obtained from discarded containers, boxes, and cans. The teacher may choose to copy some of the food labels in order to provide more labels per student.

Procedure:

If there is a large number of food labels available, students may work independently during much of the activity. If there are only two or three labels per student, the students should work in groups to share the labels and do their calculations. When students are doing food group and meal planning, they should work in groups of three to six students.

The Food Label Chart and the Student Worksheet provide a framework for data collection, organization, and interpretation. The teacher should complete the Food Label Chart and Worksheet for Nacho Cheese Soup/Dip with the students in order to develop the concept of a constant and calculate equations with conversion factors. The labels describing the terms, e.g., "calories per serving," are important and should be used consistently. Without such labels, the students can easily become confused on the appropriate placement of the numbers.

Food Label Chart and Worksheet for Nacho Cheese Soup/Dip

Directions: Look at the "Nutrition Information Per Serving" for the Nacho Cheese Soup/Dip label. Complete the Food Label Chart and Worksheet for the Nacho Cheese Soup/Dip label.

Food Label for Nacho Cheese Soup/Dip

	Nutrition Information Per Serving
Serving Size	
Servings per Container	4 oz.
	2 1/4
Calories	
Protein (grams)	100
Total Carbohydrates (grams)	4
Simple Sugars (grams)	5
Complex Carbohydrates (grams)	1
Fat (grams)	4
Sodium	8
	60 mg/serving
	Percentage of U.S. Recommended Daily Allowances (U.S. RDA)
Protein	
Vitamin A	6%
Vitamin C	30%
Thiamine	10%
Riboflavin	•
Niacin	•
Calcium	•
Iron	10%
	2%

Food Label Chart

Food Source: ______________________________

_______ = grams per serving

(grams = 28.4 x ____ oz.)

calories/serving = _______ cal/serve

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	Fat
1. gm/serving	gm
2. calories/gram	9.3 cal/gm
3. calories/serving	cal/serve
4. percent calories	% cal
5. American average	42.0% cal
6. recommended average	30.0% cal

Compare the percentage of calories from fat for this food with the current level in the average American diet and the recommended level that should be in the diet.

	Circle One:
____________ % of calories from fat.	
Compared to the American 42% average?	Greater Same Less
Compared to the recommended 30% maximum?	Greater Same Less

Worksheet

Procedures and calculations for food source:

The name of the food, grams per serving (serving size), and the calories per serving can be obtained directly from the food label. Find this information on the Nacho Cheese Soup/ Dip label and enter on the Food Label Chart.

1. The weight of fat in each serving of the food can be obtained directly from the food label. Find this information and enter in the appropriate column of the Food Label Chart.

2. The number of calories in each gram of fat is a constant and is already given in the chart. Each gram of fat gives us 9.3 food calories of energy. This value is a property which does not vary with the food source.

3. The calories of fat in each serving of this food source can be determined by multiplying the number of calories of fat from one gram of fat times the number of grams of fat in a serving.

fat (cal/gm) x fat (gm/serving) = fat (cal/serving)

9.3 (cal/gm) x 8.0 (gm/serving) = 74.4 (cal/serving)

4. a. Percentage is defined as the parts per 100, or out of 100. In the case of the percent of calories contributed by the fat in the Nacho Cheese Soup/Dip, we have 74.4 parts (calories) due to fat out of 100 calories total for each serving. This is 74.4 parts out of 100 or 74.4%.

If we had picked a food with 200 calories per serving, the 74.4 calories would have been out of 200 calories. This would mean that the 74.4 calories would have to be divided in half to determine how many calories due to fat were available to each 100 calories of a serving. It takes twice as much fat for 200 calories than it would take for 100 calories.

A proportion method is helpful in order to calculate the percent of calories contributed by a nutrient for a food that contains something other than 100 calories. In general:

$$\frac{\text{part}}{\text{total}} = \frac{\text{percentage}}{100}$$

For our activity:

$$\frac{\text{nutrient calories per serving}}{\text{total calories per serving}} = \frac{\text{percent calories}}{100}$$

$$\frac{\text{74.4 calories of fat per serving}}{\text{200 calories per serving}} = \frac{\text{percent calories}}{100}$$

percent calories of fat = 37.2%

b. Make a set of 100 centimeter cubes. For the Nacho Cheese Soup/Dip: Make a subset of cubes to represent the percent of calories contributed by the fat (to the nearest whole unit). Calculate the percent of calories contributed by the other nutrients and make a subset of cubes to represent this percent. Place the cubes on the floor to make a bar graph representing the percent of calories contributed by fat and contributed by the other nutrients.

c. Draw a bar graph on graph paper to represent the percent of calories contributed by fat and contributed by the other nutrients. Use one-half centimeter graph paper so that the scale is one-half centimeter square represents two calorie percentage units.

5. The resulting percentage of calories from fat can be compared to the American average and the recommended average for our diets. It makes more sense to make these comparisons using a variety of foods which represent a single meal or a day's food intake.

Evaluation:

Students will submit their Food Label Charts and Student Worksheets showing their calculations of the percentages of calories due to fat content and other nutrients in the foods. Student-constructed bar graphs should also be evaluated.

Teacher Notes:

Note #1: It is suggested that students with the teacher's assistance complete the Food Label Chart and Worksheet for the Nacho Cheese Soup/Dip.

Note #2: Students should be encouraged to select labels from foods that interest them. They should be encouraged to hypothesize about the quality of a food before they do the calculations. The teacher may encourage speculation by asking: "Does whole milk contain an acceptable percentage of its calories from fat?"

Note #3: Students should use calculators to complete the Food Label Chart and Student Worksheet.

Note #4: The completed Food Label Chart for the Nacho Cheese Soup/Dip is provided:

Food Source: Nacho Cheese Soup Dip
113.6 = grams per serving
(grams = 28.4 x 4 oz.)
calories/serving = 100 cal/serve

	Fat
1. gm/serving	8.0 gm
2. calories/gram	9.3 cal/gm
3. calories/serving	74.4 cal/serve
4. percent calories	74.4% cal
5. American average	42.0% cal
6. recommended average	30.0% cal

74.4% of calories from fat. Circle One:
Compared to the American 42% average? [✓ Greater] Same Less
Compared to the recommended 30% maximum? [✓ Greater] Same Less

Note #5: Centimeter cubes or squares to develop the concept of percents and make bar graphs are included in multibase blocks, cuisenaire rods, hundreds board, centimeter graph paper, and decimal squares. Many of these square units are available as concrete and overhead transparent materials.

Note #6: If one-half centimeter graph paper is unavailable, the teacher may choose to draw lines dividing the squares on one centimeter graph paper and then make copies for students to use. The teacher may choose to use graph paper with different size units and then discuss appropriate scaling.

Note #7: The teacher may choose to do items 3 and 4 on the Student Worksheet as a total class activity. If these activities are done by students in small groups, it is suggested that there be a follow-up discussion by the whole class comparing rankings for the four food groups and the results from the various meals.

Note #8: The teacher may want to draw three bar graphs (one each for breakfast, lunch, and dinner) for the overhead projector based upon the data collected in item 4. Using different color marking pens, the bar graphs could show the different percentages of calories from fat in the various menus planned for breakfast, lunch, and dinner.

Extensions:

1. The students may want to explore the calorie content of other nutrients listed on food labels. The Food Label Chart and Student Worksheet can be modified by changing the constant or the number of calories in each gram contributed by the particular nutrient.

2. Two appropriate computer software programs are: *Nutrition* and *Food Facts* published by the Minnesota Educational Computing Consortium and *Food for Thought* published by Sunburst Communications.

3. The students may want to explore the calories from fat from meals consumed on a daily basis. The Student Worksheet could be modified by calculating and using the total grams from fat and the total calories for a breakfast, lunch, and dinner.

Student Worksheet

1. Select a sample of six Food Label Charts. For each Food Label Chart:

a. Divide a set of 100 centimeter cubes into a subset of cubes to represent the percent of calories contributed by the fat (to the nearest whole unit). Calculate the percent of calories contributed by the other nutrients and make a subset of cubes to represent this percent. Place the cubes on the floor to make a bar graph representing the percent of calories contributed by fat and contributed by the other nutrients.

b. Draw a bar graph on graph paper to represent the percent of calories contributed by fat and contributed by the other nutrients. Use one-half centimeter graph paper so that the scale is one-half centimeter square represents two calorie percentage units.

c. Draw a bar graph on graph paper to represent the percent of calories contributed by fat for the sample of six food labels. Use one-half centimeter graph paper so that the scale is one-half centimeter square represents two calorie percentage units.

2. The U.S. Senate Select Committee on Nutrition and Human Needs in 1977 recommended that Americans should change their calorie consumption of the following foods:

Nutrient	Percentage of Calories	
	Current Level	Recommended Level
Fat	42%	30% or less
Refined and processed sugars such as sucrose	18%	10% or less
Starches and naturally occurring sugars such as fructose in fresh fruit	28%	48%
Protein	12%	12%

Use all of your Food Label Charts and rank order the foods from the most recommended to the least recommended food in terms of its fat content. In other words, order the foods from the smallest percentage of calories from fat to the largest percentage of calories from fat.

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3. Make a group of three to six people. Share your information with these students. As a group, identify at least one food from each of the four food groups: (1) milk-cheese group, (2) meat-poultry-fish-bean group, (3) vegetable-fruit group, and (4) bread-cereal group.

Compare the percentage of calories from fat for each of the foods from each food group with the recommended maximum level of 30% that should be in the diet.

Rank order the food groups from the most recommended to the least recommended food group in terms of its percentage of calories from fat.

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4. As a group, organize a menu for a breakfast, lunch, or dinner meal using the foods on your Food Label Charts. Complete the following chart to calculate the percentage of calories contributed by fat in the entire meal.

Meal: Breakfast Lunch Dinner (circle one)		
Food Sources:	Fat grams per serving	Calories per serving
Food #1 __________	__________	__________
Food #2 __________	__________	__________
Food #3 __________	__________	__________
•		
•		
•		
Food #n __________	__________	__________
TOTAL	a. ______ gm	b. ______ cal.
c. calories/fat gram	9.3 cal/gm	
d. fat calories/meal	______ cal/meal	
e. other calories/meal	______ cal/meal	
f. fat calories/meal calories	______ cal/meal	
g. percent calories/meal	______ % cal	
h. American average	42.0 % cal	
i. recommended average	30.0 % cal	

Procedures and calculations:

a. Total the grams of fat per serving for the foods in your meal.

b. Total the calories per serving for the foods in your meal.

c. The number of calories in each gram of fat is constant (9.3).

d. Multiply the total grams of fat by 9.3 calories per gram to give the total calories from fat for the foods in your meal.

e. Subtract the total calories from fat for the foods in your meal from the total calories in your meal. The difference is the calories from other nutrients found in the foods in your meal.

f. Divide the total calories from the fat for the foods in your meal by the total calories in the meal.

g. Multiply by 100 to give the percentage of calories from fat for the foods in your meal.

h. Compare the percentage of calories from fat in this meal to the current level in the average American diet.

i. Compare the percentage of calories from fat in this meal to the recommended level for fat in the diet. Is this a good nutritious meal?

j. Draw a bar graph on graph paper to represent the percent of calories contributed by fat and contributed by the other nutrients for the foods in your meal. Use one-half centimeter graph paper so that the scale is one-half centimeter square represents two calorie percentage units.

k. You may wish to continue organizing better menus. Predict what would be a good nutritious meal and then do the calculations to demonstrate that it meets (or fails to meet) the recommended guidelines.

Early Days

J. Steve Oliver, Editor

Correct Mental Images: Volume 1, Number 7

The last issue of *School Science* in 1901 began with an article titled "The Application of Statistics to Evolution Studies" by Chas. B. Davenport of the University of Chicago. In the article, Davenport explained his research on the "bivalve mollusc, *Pecten irradians*." He described his use of histograms and frequency polygons to show the size classes of the organisms. The conclusion that Davenport drew from this work was that "When the polygon is symmetrical about the modal ordinate we may conclude that no evolution is going on; that the species is at rest. But very often the polygon is more or less unsymmetrical or 'skew.' A skew polygon is characterized by this: that the polygon runs from the mode further on one side than on the other. This result may clearly be brought about by the addition of individuals to one side or their subtraction from the other side of the normal frequency polygon. The direction of skewness is toward the excess side. The skew frequency polygon indicates that the species is undergoing an evolutionary change. Moreover, the direction and degree of skewness may tell us something of the direction and rate of that change" (p. 341).

John M. Holzinger, of the State Normal School in Winona, Minnesota, wrote an article for this issue of *School Science* titled "Astronomical Observations in Geography." He, like many people today, made a strong statement about the lack of knowledge among students concerning geographical questions. "Probably the strongest argument for such work is to be drawn from the almost uniformly unsatisfactory answers given by high school graduates to geographical questions involving a concrete knowledge, as opposed to a verbal knowledge, of such easily demonstrable facts as the earth's daily motion on its axis. Correct mental images of the earth as a sphere, and of the position of the plane of the observer's horizon in all latitudes, are not derivable from the committing of the formal phrases and diagrams of a book. Certainly not one student in a hundred who has been taught geography according to present methods is able to imagine for himself with any degree of adequacy the dependence of daily phenomena upon the observer's latitude—and is this not quite as valuable to him as the commonly current dallying with the papooses of the Esquimaux?" (p. 345-346). He gave many examples of the types of observations that should be made and then concluded, "Some of the most important facts of geographical knowledge are the cardinal dates, the cardinal points, the lines of latitude and of longitude, the decrease pole-ward of the sun's heat and the effect of this changing condition upon human existence in high as well as low latitudes. An effective

SSMILES

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Time Travel: Negative Numbers
Grades 4-6

Mathematics Concepts/Skills	**Science Concepts/Processes**
greater than, less than, serial order, counting backwards, negative numbers, subtraction of signed numbers, use of a calculator, scaling	time relationships, history of science, measurement, calendar system, time line (B.C., A.D., c.)

Prerequisite Skills:

Addition, subtraction, reading a thermometer, counting

Objectives:

1. Students will order a series of historical, scientific events based upon pictures depicting these events.
2. Students will order historical, scientific events based upon their B.C. and A.D. dates.
3. Students will compute differences using positive and negative numbers.
4. Students will compute time elapsed between historical, scientific events.

Rationale:

The history of science is both interesting and revealing. Important scientific discoveries have been made and theories have been conceived, revived, changed, and improved upon. These advancements in science led to inventions and technological developments which have a profound influence upon our lives. In viewing history, our system of counting time uses the terms B.C. and A.D. In order to understand this numbering system, students need an understanding of negative numbers and addition and subtraction with negative numbers.

Lesson Outline:

Time: Two 50-minute class periods
Materials:
Set of numbered pictures depicting historical events in science
Cord and clothes pins
Time line
Large thermometer
Overhead projector or chalkboard
Calculators (at least one for every two students)
Preparation:

You will need a teacher-made set of pictures depicting historical events in science. These can be cut from old science books, magazines, or posters mounted on cardboard, and dated on the back. A representative list of some historical events in science is included in Teacher Note #1. The teacher should choose events which fit the needs and interests of the class.

Procedure:

1. Use the numbered set of picture cards depicting historical events in science. Have the students sort the cards into two piles—those that happened in ancient times and those that happened in modern times. Let the students define "ancient" and "modern" times and discuss the need to be more precise when dating events.
2. Using clothespins, hang the picture cards on a cord strung across the chalkboard for students to view. Using the numbered picture cards, have students attempt to order them from most ancient to most recent events. Encourage students to provide reasons for their ordering of events.
3. Flip the picture cards over to reveal the dates on the back. Write the dates on the chalkboard beneath each picture. Flip the cards again so that the picture shows.
4. Discuss how to determine the ordering of historical, scientific events using the dates on the chalkboard. In the discussion include:
    a. the meaning of the terms B.C. (before Christ), A.D. (anno Domini or in the year of Our Lord; after Christ), and c. (circa or about),
    b. if a date is not labeled B.C. or A.D. it should be assumed that it is A.D., and
    c. when looking at events with B.C. dates, events with larger number dates occurred before those with smaller number dates.
5. Have students order the picture cards from the earliest to the most recent historical event in science based upon the dates on the chalkboard. As they move each picture card, change the date on the chalkboard to correspond to the date of the scientific event. Compare the actual order of the events with the class ordering of events. Discuss the events and their importance.
6. Discuss times when students may have used numbers that are less than zero (e.g., game scoring, yardage losses in football, owing money, below sea

level, below ground level). Examine a vertical thermometer to show positive and negative numbers related to zero. Show how these numbers are written. Compare the relative coldness of temperatures such as +10° and −10° or −10° and −20°.

7. Pass out the calculators to students. Have students use the calculators to count backwards from 10 to −10 by repeated subtraction of one using the constant function. Have students discuss what happens on the display as you pass zero. Discuss the minus sign and what it means.

8. Have students use their calculators to compute differences between temperatures. Include examples such as: a) from 27° to 12°, b) from 18° to −4°, and c) from −16° to −29°. Lay the thermometer in a horizontal position with the bulb (or coldest temperature) on the left. Compare the position of the below zero degrees and above zero degrees to B.C. and A.D.

9. Draw a time line on the chalkboard beneath the pictures. Have students discuss how to divide the time line and appropriate labels. A discussion about the length of the line segments and the year intervals (i.e., scaling) related to the perception of time elapsed should be encouraged. (See Teacher Note #2.) Divide the time line and write in the year labels. Position the picture cards on the time line.

10. Have students draw their own time line labeling the year intervals. Have students draw an arrow to the appropriate year of each event in science history using the space above and below the time line. Have students label the events.

11. Dramatically introduce the calculator as the control panel of a time machine. Have them punch in the current year as a starting place. Tell them that they will be traveling back in science history to events discussed earlier. The students will need to find the activator number to take their time machine to the desired year. This activity may be effectively demonstrated using a transparent calculator on an overhead projector. Give them time to experiment. Give students various events and years in science history. Discuss how the activator number represents the number of years between the current year and the event in science history. Discuss the relationship between subtraction between A.D. and B.C. dates and subtraction between positive numbers and negative numbers and the role of a relative zero.

Evaluation:

1. Give students groups of 3 or 4 scientific developments which they should put in order from oldest to most recent.

2. Give students a series of problems to determine the number of years which have passed since specific scientific developments (see Teacher Note #3).

3. Give students a series of problems to determine the number of years which have elapsed between specific scientific developments (see Teacher Note #3).

Teacher Notes:

1. Events in the history of science (*The World Book Encyclopedia 1988 Edition*) could include:

3000 B.C.	Egyptians studied the heavens to predict the seasons and used geometry for property lines and building the pyramids.
c.600s B.C.	Thales, Anaximander, and Anaximenes theorized about the nature and creation of matter.
c.500s B.C.	Pythagoras laid the foundations of modern geometry.
	Anaxagoras suggested that the sun and stars were material objects, not gods.
	Democritus suggested that everything was made up of atoms, minute particles of matter.
c.400 B.C.	Hippocrates taught that diseases have natural causes; he considered medicine a science apart from religion.
c.300 B.C.	Aristotle recognized the importance of observation, the need for classifying knowledge, and developed deductive logic in his study of animals and plants.
	Euclid organized geometry as a single system of mathematics.
	Chinese had mapped the major stars in the heavens.
	Indians had invented the Hindu-Arabic numerals.
200s B.C.	Archimedes discovered the laws of the lever and the pulley, the displacement of water, and the calculation of the area of a circle.
	Eratosthenes devised a system for measuring earth.
A.D. 100s	Ptolemy proposed that the earth is the center of the universe in his geocentric theory. Galen developed the first medical theories based upon experiments and advanced the field of anatomy. Hipparchus worked out the mathematics of planetary movement.
250	Mayans used their knowledge of astronomy (motions of the sun, moon, stars, and planets) to develop religious and civil calendars.
800s	Al-Khowarizmi organized and expanded algebra.
c.1000s	Avicenna produced a medical encyclopedia called the *Canon of Medicine*.
1200s	Bacon showed how a lens could make objects appear nearer using what may have been similar to a microscope.
1400s	Aztecs represented the regular motions of the heavenly bodies in their "Calendar Stone."
	Incas used mathematics to construct buildings and roads.
c.1500s	Leonardo da Vinci studied anatomy, astronomy, botany, and geology.
1543	Copernicus revolutionized astronomy with his sun-centered (heliocentric) theory.
	Vesalius wrote the first scientific text on human anatomy.

1600s	Newton demonstrated that sunlight is a mixture of light of all colors and began the study of optics
	Newton and Leibniz independently developed a new system of mathematics, calculus.
	Galileo used mathematics to explain the effects of gravity; he designed the pendulum clock and telescope in his quest for precise scientific instruments.
	Hooke used the microscope to discover the world of cells.
	Boyle helped establish the experimental method in chemistry.
1609	Kepler identified the elliptical orbit of the planets and established astronomy as an exact science.
1628	Harvey published his theory on how the blood circulates.
1687	Newton published the law of universal gravitation.
1700s	Scheele and Priestley independently discovered oxygen.
	Linnaeus developed a systematic method for naming and classifying animals and plants.
	Galvani and Volta experimented with electric current.
1752	Franklin proved that lightning is electricity by using a kite during a thunderstorm.
1777	Lavoisier discovered the nature of combustion.
1800s	Schleiden and Schwann theorized that cells make up all organisms.
	Mendel discovered the basic statistical laws of heredity which became the basis for the science of genetics.
	Pasteur found that certain microscopic organisms can cause disease which became the basis for the science of microbiology.
1820	Oersted found that a wire would become a magnet when an electric current flows through a coil of the wire.
1825	Sturgeon sent an electric current through a copper wire wrapped around a horseshoe bar of varnished iron to make an "electromagnet."
1829	Henry covered some wire with silk and found that the more he coiled the "insulated" wire around a bar, the stronger the magnet became.
1830	Lyell showed that the earth has changed slowly through the ages.
1831	Faraday and Henry independently produced an electric current with a moving magnet.
1859	Darwin published his theories of evolution based upon the unity of living organisms and changes over time due to natural selection in his *The Origin of Species.*
1860s	Maxwell developed his electromagnetic theory which states that visible light consists of waves of electric and magnetic forces.
1869	Mendeleev published his periodic table of the elements.

1880s	Hertz produced electromagnetic waves that led to the development of the radio, radar, and television.
1898	The Curies isolated the element radium.
1900s	Ehrlich began the treatment of diseases with chemicals which established the field of chemotherapy.
	De Vries described mutations as changes in the hereditary materials of cells.
1900	Planck set forth his quantum theory to explain the spectrum of light emitted by certain heated objects.
1905	Einstein published his theory of relativity and dramatically changed scientific thinking about space and time; he also showed that light consists of individual energy units which he termed photons.
1910	Morgan and his co-workers proved that genes are the units of heredity and that genes are arranged in an exact order along the chromosomes.
1911	Rutherford outlined his theory of atomic structure which states that the mass of an atom is concentrated in a tiny nucleus which is surrounded by rapidly moving electrons.
1913	Bohr described the electron structure as traveling in a set of definite orbits around the nucleus.
1920s	Muller discovered that mutations could be produced by X-rays.
1928	Fleming discovered penicillin, the first antibiotic.
1930s	Two teams, Hahn and Fritz and Strassman and Meitner, discovered the possibility of releasing energy by splitting atoms of uranium.
1942	Fermi and his co-workers created the first controlled nuclear chain reaction.
1953	Salk produced the polio vaccine.
	Watson and Crick built a ladderlike model of DNA, the substance that controls heredity.
1957	The Soviet Union launched the first artificial satellite.
1965	The United States and the Soviet Union photographed Mars using unmanned spacecrafts.
1969	The crew of the United States Apollo 11 were the first human beings to walk on the moon.
1974	Researchers developed the first recombinant DNA procedure.
1978	The Pioneer Venus I was the first American spacecraft to orbit Venus.
1981	The United States launched the Columbus, the first reusable manned spacecraft.
1989	An American spacecraft named the Voyager photographed Neptune.

The teacher may want to provide students with events related to one specific area or theme of scientific development. This list is only a sample of events.

2. The time lines used should range from the earliest to the latest date of a scientific event (or the current date) and be divided into equal line segments related to the intervals between the selected scientific events.

3. Encourage students to use mental arithmetic, paper and pencil algorithms, and calculators where appropriate.

Extensions:

1. Students can research historical, scientific events related to specific themes (e.g., anatomy, astronomy, biology, chemistry, communication, computer technology, genetics, geology, physics, psychology, the universe, transportation), construct time lines, and mathematically compare the time between events.

2. Scientific advancements have been related to political, social, economic, philosophical, and cultural movements in history. Students could research the Greek and Roman Eras, the Middle Ages, the Renaissance, the Age of Reason (or Enlightenment), the Industrial Revolution, the Atomic Age, the Space Age, the Age of Technology, the Information Age, etc., and discuss these time periods as related to scientific developments. They could construct time lines and mathematically compare the time between events in each period of time.

3. Students can do research related to inventions and technological developments. They can construct a time line showing the dates of scientific discoveries and their correspondence to the dates of inventions and technological developments.

4. Time lines can be constructed using the year of birth of most of the students in the class as the relative zero. The students can then relabel the points on the time line for an appropriate set of science events before and after their birth. Students can compute how many years elapsed before or after their birth for each scientific event.

5. Students can make time lines for developments in air and space travel using the Soviet Union launch of the first artificial satellite (1957) as relative zero. Students can research historical, scientific events in air and space travel, construct their own time lines, and mathematically compare the time between events.

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SSMILES

Donna F. Berlin, Department Editor

This month's SSMILES is an activity for grades 4-6 called "Soil Structure and Ground Water" which is one of many activities that can be found in the School Science and Mathematics Association monograph *Classroom Activities Series #2*. This monograph is written by Walter A. Farmer, Professor of Science Education, and Margaret A. Farrell, Professor of Mathematics Education, at the State University of New York at Albany. It is the product of the collaborative effort of the mathematics and science education faculty at the State University of New York at Albany and representatives of eight school districts in the Capital District Area in a project funded by the New York State Education Department.

The monograph is a collection of activities designed to teach math/science concepts and meet the following criteria: (a) combine important mathematics and science learnings in a single lesson; (b) have been tried out by classroom teachers and elementary school children; (c) involve "hands-on" activity; and (d) use readily available, everyday materials. The activities are generally identified for grades kindergarten through third and fourth through sixth but can be adapted to meet the needs of other grade levels.

The monograph, published Spring 1989, can be ordered from: Executive Office, School Science and Mathematics Association, Bowling Green State University, 126 Life Science Building, Bowling Green, Ohio 43403-0256, telephone (419) 372-7393.

Soil Structure and Ground Water

Procedure: Show students two large, clear, colorless plastic soda containers (with necks cut off at the shoulders). Fill one with water to the 2 liter mark and call attention to the other gradations marked on the container with magic marker. Place the larger sized rocks in the other container until it is filled to the top. Ask if this container is now full of rocks. When the students point out the empty spaces, display the small pebbles (or marbles). Pour these in while banging the container on the table to settle material into the spaces. Again, question the students about the fullness of the container of rocks and pebbles (or marbles). Then add dry sand and tap the container to distribute

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the sand as thoroughly as possible into the remaining spaces. Point out that we have created a good model of what the earth beneath our area is like—a mixture of large and small rocks with sand and soil materials. At this point, ask if all the spaces have been filled. Some may suggest that there might be some room for a little water. If not, suggest the possibility and elicit predictions of how much. Record the predictions and then slowly add water to fill the container and record the amount. Make the connection to rain and melting snow seeping into the ground and being stored in all those too-tiny-to-see spaces. Question the students about water wells and their importance in tapping this ground water for use in city as well as in rural areas.

Materials: Two clear, colorless plastic soda containers (2 liter), large and small rocks or marbles, gravel, etc. of suitable size for the container, dry sand, magic marker to mark the water container gradations.

Key Concepts, Skills, and Processes:

Mathematics: Concepts of capacity (volume) and space; processes of estimating volume and inferring.

Science: Same as mathematics and also concepts of soil structure, ground water, water supply.

Background: The concept of volume is one with which students at this level need more experience. (Even older students who can compute volumes of rectangular solids have been found to have little idea of the relationship of the final product to the interior space.) Also, they will need reminding that the spaces observed were really full of air, as were the empty containers at the start of the demonstration. Note how the demonstration proceeded from the obvious (large, easily visible spaces) toward the much less obvious (evidence for spaces too small to be visible to the human eye). A common misconception is that wells are typically deep holes drilled into underground lakes.

Extensions: Have students research information about the water supply systems that serve homes and industries in the local area. All high school earth science textbooks contain sections on ground water and wells. One or more students with artistic skills might enjoy preparing a cross-sectional diagram of a well for class use. For further work on developing the concept of volume in the form of liquid capacity, use several containers of different shapes (different heights, different widths, . . .) but all holding the same amount of liquid. Pour colored water into these, one at a time. Have students estimate whether there is more water or less water in particular containers. Let them check their predictions by measuring the water into a common container.

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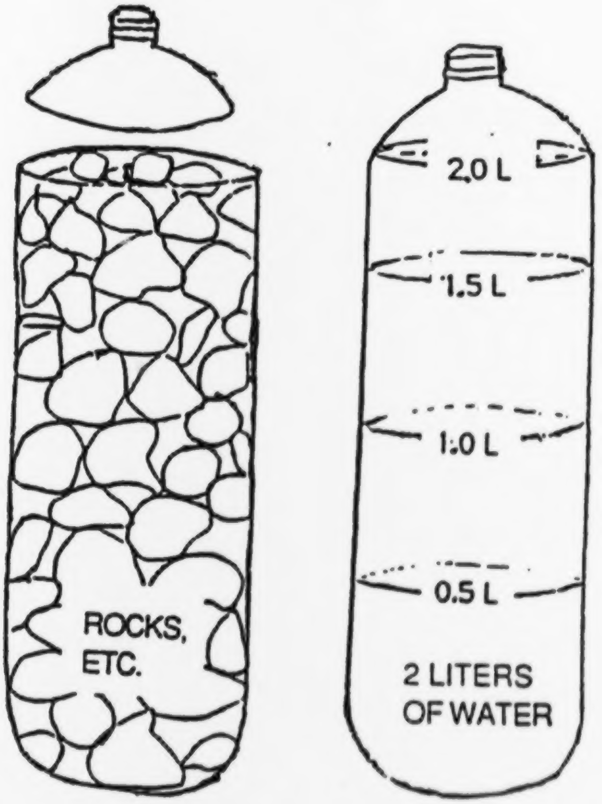
CUT OFF TOP AND SHOULDERS.


ROCKS, ETC.
2.0 L
1.5 L
1.0 L
0.5 L
2 LITERS OF WATER

SOAK BOTTOMS IN HOT WATER. THEN TWIST OFF BLACK COVERS.

SSMILES

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The Geometry of Parallel Plate Refraction
High School/College

Mathematics Concepts/Skills	Science Concepts/Processes
parallel lines and planes, normal lines, geometric proofs, trigonometric definitions and identities	parallel plates, incident and emergent angles, displacement of refracted images

Prerequisite Skills:

The students should have:

1. an understanding of parallel line theorems from geometry,
2. knowledge of the definitions of normal lines and trigonometric functions, and
3. the ability to write geometric proofs.

Objectives:

1. To determine the relationship between the displacement of light rays passing through a plate of transparent material and the angle of refraction for that material.
2. To identify other important factors in that relationship.

Rationale:

One of the most common instances of refraction is the displacement of images seen through plate glass windows. Light from the image strikes the surface of the glass at some angle, and is refracted to some other angle. As the light passes through the opposite surface of the glass it is refracted again, emerging parallel to the original incident light rays.

We will use the principles of geometry and trigonometry to find a relationship between the displacement of the light rays and the angle of refraction for a common transparent material, glass. We will assume that the plate of glass has parallel plane surfaces.

School Science and Mathematics
Volume 90 (5) May/June 1990

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Content Background:

The following concepts are critical to the proper understanding of our model: parallel plates, normal lines, angles of incidence, refraction, and emergence, definitions of sine, cosine, and tangent, sine angle addition formula, definition of arctangent, and displacement.

Parallel plates are transparent materials with parallel plane surfaces.

Normal lines are lines perpendicular to a surface or a line. The normal lines most useful to us will be those passing through the points where the light rays touch the surface of the parallel plate.

The angle of incidence is the angle between the incident light ray and a line normal to the surface it strikes.

The angle of refraction is the angle between the refracted light ray and a line normal to the surface.

The angle of emergence is the angle between the emergent light ray and a line normal to the surface that it is leaving.

Displacement means the perpendicular distance between the line containing the incident light ray and the line containing the emergent light ray.

The sine of an angle A is defined relative to the right triangle below as

$$\sin A = a/c$$

The cosine of an angle A is defined, relative to the same triangle, as

$$\cos A = b/c$$

The tangent of an angle A is defined by

$$\tan A = a/b$$

The Sine Angle Addition Formula states that

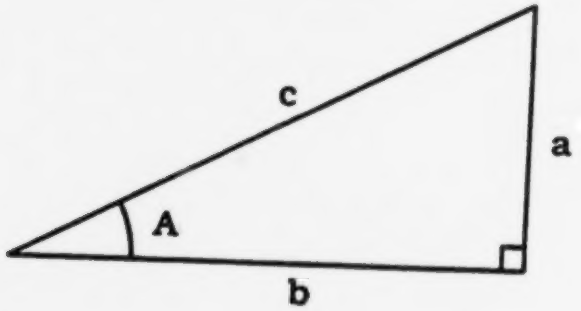
$$\sin (A + B) = \sin A \cos B + \cos A \sin B$$

or

$$\sin (A - B) = \sin A \cos B - \cos A \sin B$$

The arctangent or inverse tangent is the function which relates the ratio of the legs of the given right triangle to the angle A. Given the lengths of the sides, we can find the angle by

$$A = \arctan (A/b)$$



Lesson Outline:

Time: Three to four 45-minute periods

Materials/Supplies per Student:

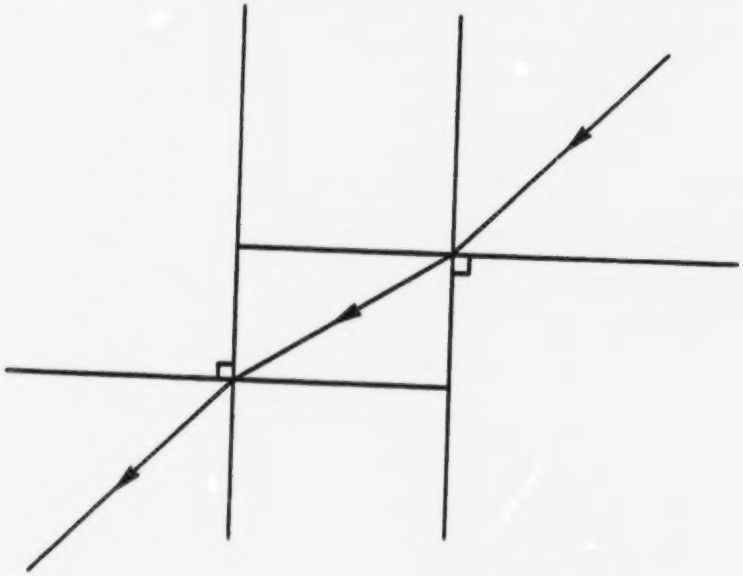
- Parallel Plate Diagram
- Student Worksheet
- Access to standard geometry and trigonometry textbooks
- Straight edge

Procedure:

Using the Student Worksheet, have students work on 1 or 2 of the problems in each 45-minute period. After presenting the problem, have students break up into groups of 2 to 4 students to discuss problem solving strategies. Allow 10 to 15 minutes for discussion, then have students finish independently.

Refer to the Parallel Plate Diagram. The vertical lines represent the surfaces of a parallel plate of transparent material. The horizontal lines are normal to the surfaces of the plate. The diagonal line represents the path of a ray of light as it passes through the plate from left to right.

Parallel Plate Diagram



Student Worksheet

Problems

1. Identify the following parts of the Parallel Plate Diagram. Place the symbols that represent the various parts in appropriate places on the diagram.
    Left-hand surface of the plate—P_1
    Right-hand surface of the plate—P_2
    Incident light ray—i
    Emergent light ray—e
    Normal line at point of incidence—Ni
    Normal line at point of emergence—N_e
    Angle of incidence—A_i
    Angle of refraction—A_r
    Angle of emergence—A_e
2. Extend the incident light ray, i, and the emergent light ray, e, so that a pair of parallel lines is formed. Prove that the angle of emergence, A_e, is equal to the angle of incidence, A_i.
3. If the parallel plate has a thickness of T, what is the perpendicular distance from N_i to N_e, in terms of T and A_r?
4. Locate the segment of P_2 that lies between N_i and the line containing i. What is the length of this segment in terms of T and A_i?
5. What is the measure of the acute angle between the surface P_2 and the line containing e? Given that the displacement, or perpendicular distance, between the lines containing i and e is d, what is the length of the segment of P_2 that lies between N_e and i?
6. Express A_r as a function of A_i, d, and T.

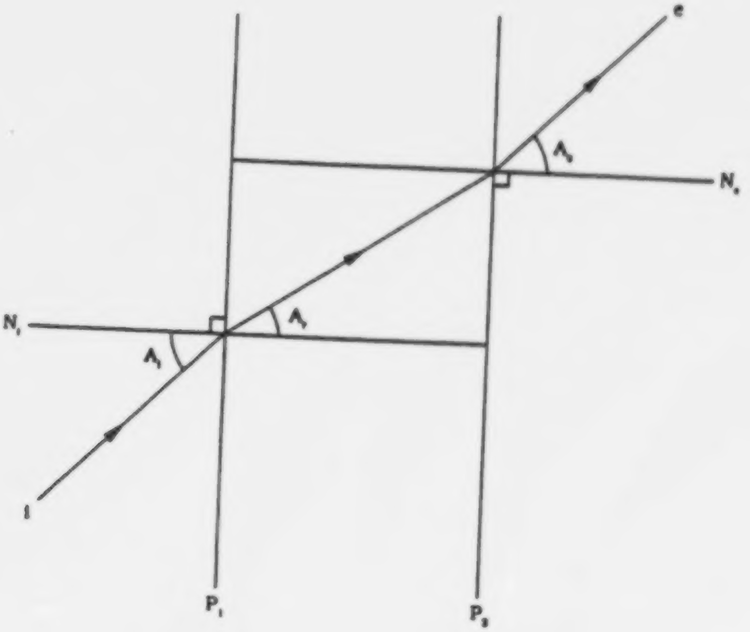
Evaluation:

Students will be evaluated on the completeness and correctness of problems 1-6 on the Student Worksheet. Students' participation in group discussions of problems will also be evaluated.

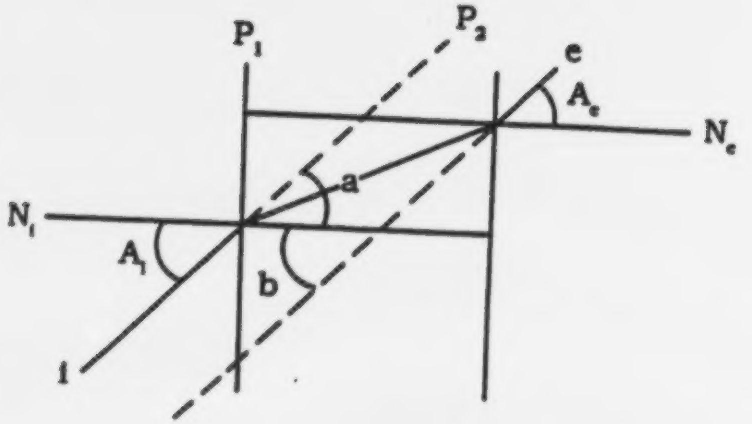
Teacher Notes:

Proofs and Derivations for Problems 1-6 on the Student Worksheet

1. Parallel Plate Diagram



2. We are given that P_1 is parallel to P_2, i is parallel to e, N_i is perpendicular to P_1, and N_e is perpendicular to P_2. We can begin with either the parallels or the perpendiculars. We will start with the parallels. It will be helpful to break the proof into several steps. First, let us examine the relationships between lines N_i, i, and e.



Since vertical angles are equal,

$$A_i = a$$

And, since a and b are alternate interior angles,

$$a = b$$

Therefore, by transitivity,

$$A_i = b.$$

Next we need to prove that N_i is parallel to N_e. Now, since N_i is perpendicular to P_1, and P_1 is parallel to P_2, then N_i is perpendicular to P_2. And, if 2 lines in a plane are perpendicular to the same line, then they are parallel to each other, which gives us N_i parallel to N_e since they are both perpendicular to P_2 (see figure at top of page 433).

Our final step in the proof that $A_i = A_e$ uses the lines N_i, N_e, and e (see figure at bottom of page 433).

Now, since N_i is parallel to N_e, and since alternate exterior angles of parallel lines are equal,

$$A_e = b.$$

But we've already proved that

$$A_i = b.$$

And so, by the transitive property,

$$A_e = A_i.$$

3. To find the distance from N_i to N_e, we examine the triangle containing the angle of refraction A_r (see figure at top of page 434).

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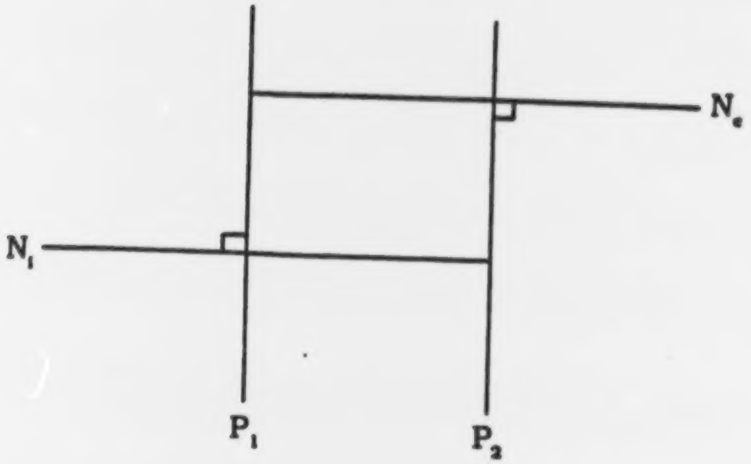
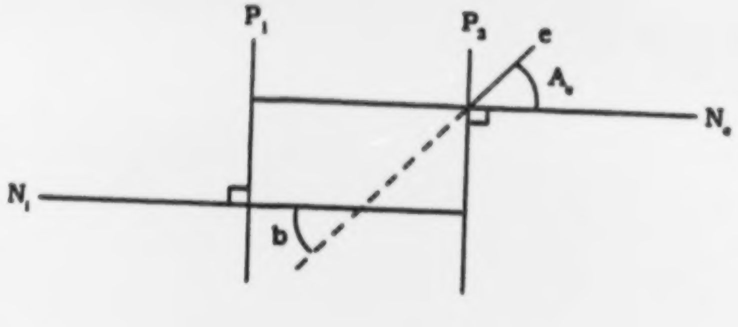
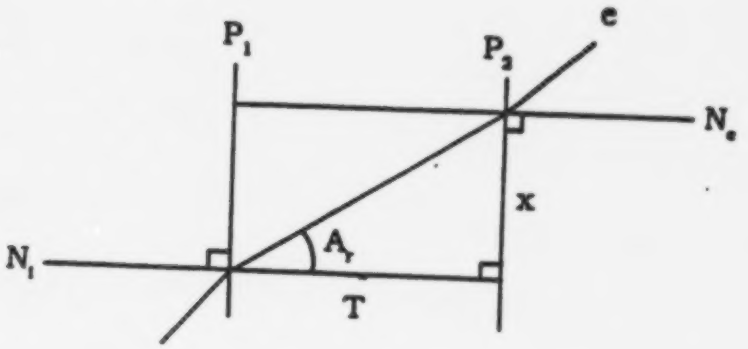

N$_e$
N$_i$
P$_1$
P$_2$


P$_1$
P$_2$
e
A$_e$
N$_e$
N$_i$
b



We are given that the base of this triangle has a length T, and we know, since N_i is perpendicular to P_2, that this is a right triangle. The distance between N_i and N_e, x, can be found, in terms of A_i and T, by using the definition of tan A_r

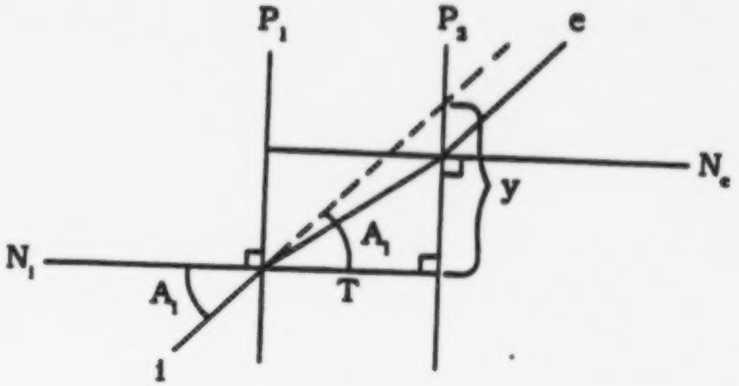
$$\tan A_r = x/T$$

or

$$x = T \tan A_r$$

4. Similarly, the distance from N_i to i along P_2 can be found to be

$$y = T \tan A_i$$

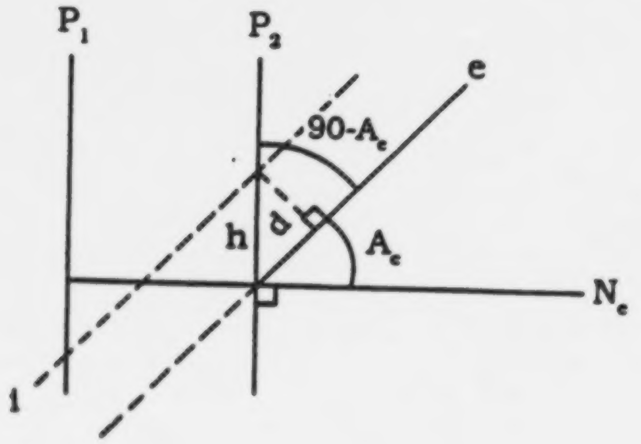


5. The acute angle between P_2 and e is the complement of A_e, and is thus equal to $90° - A_e$. The length of the segment of P_2 between N_e and i can be found by using the definition of $\sin(90° - A_e)$.

$$\sin(90° - A_e) = d/h$$

where h is the length of the segment, and d is the displacement between i and e. If we solve this for h, we get

$$h = d/(\sin(90° - A_e))$$



Now, by the Sine Angle Addition Formula,

$$\sin(90° - A_e) = \sin 90° \cos A_e - \cos 90° \sin A_e = \cos A_e$$

And, since $A_i = A_e$,

$$\cos A_e = \cos A_i$$

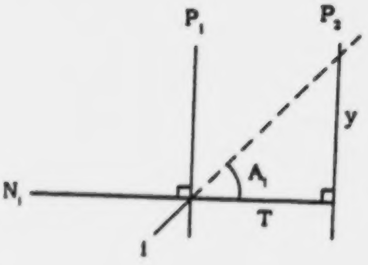
so,

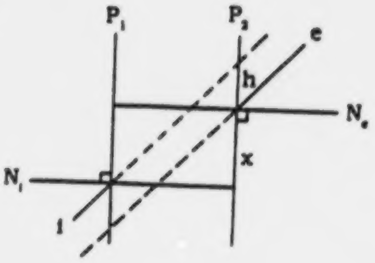
$$h = d/(\cos A_i)$$

or

$$h = d \sec A_i$$

6. To express A_r in terms of A_i, d, and T, let us look at the distance between N_i and i along P_2.





From problem 4, we have this distance

$$y = T \tan A_i.$$

While, if we add the lengths of the 2 segments that make up this segment, we find

$$y = x + h = T \tan A_r + d \sec A_i$$

Putting these equations together, we get

$$T \tan A_i = T \tan A_r + d \sec A_i$$

Solving for A_r,

$$T \tan A_r = T \tan A_i - d \sec A_i$$
$$\tan A_r = \tan A_i - (d/T) \sec A_i$$
$$A_r = \arctan (\tan A_i - (d/T) \sec A_i).$$

Extensions:

1. Encourage students to explore alternate proof strategies for Problem 2 on the Student Worksheet.
2. The Parallel Plate Diagram could be presented as a computer graphics project.

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SSMILES

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Clay Boat: A Fun Hands-on Activity
for Mathematics and Science
Grades 4-12

Mathematics Concepts/Skills

metric system, linear measurement, volume measurement, weight measurement, estimation, ratio and proportion, problem solving

Science Concepts/Processes

buoyancy, specific gravity, water displacement methods of volume measure, observing, interpreting, predicting, controlling variables

Prerequisite Skills:

Metric system, measurement of volumes of geometric solids.

Objectives:

By engaging hands-on and fun activities, students will be able to use process skills listed, construct and revise clay-boats, and use the science and mathematics concepts to solve the problems.

Content Background:

The Clay-Boat, a unit in Elementary Science Study, has been one of my favorite mathematical as well as science problem solving activities. Most of the content of the suggested activities has been restructured by me after numerous teaching experiences. Many teachers who performed the clay-boat activities as part of an inservice program enjoyed the activities because the unit had an ample amount of hands-on measurement activities and discovery-oriented science principles. Many intermediate grade students loved the unit and the opportunity to successfully complete the activities. They also had a chance to use the measurement and science principles in predicting and interpreting activities.

Lesson Outline:

Time: Two or three 45-minute periods

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Materials:

Modeling clay
Centimeter rulers
Graduated cylinder or measuring cup using metric units
Weighing scales using metric units
Marbles (or ceramic tiles)
Small jars
Thin plastic cups or paper cups
Bucket of water

Procedure:

There are six, sequenced activities. These activities can be carried out ver successfully by small groups of four or five students.

1. *Water displacement method to measure volume of a lump of modelin clay.*

Volume can be measured by showing the concept of water displacemen The water level of a jar rises when a lump of clay is submerged in the wat or a certain amount of water overflows from a jar when a lump of clay i submerged. Let the students find out that the volume of water that overflow is the same volume as that of the submerged object. Let the studen experiment with the concept of displacement using modeling clay and wate The following methods are suggested (see the diagrams in Figures 1, 2, and 3)

Figure 1.

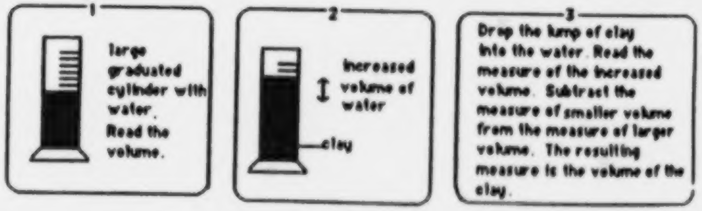

1
large graduated cylinder with water.
Read the volume.
2
increased volume of water
clay
3
Drop the lump of clay into the water. Read the measure of the increased volume. Subtract the measure of smaller volume from the measure of larger volume. The resulting measure is the volume of the clay.

Figure 2.

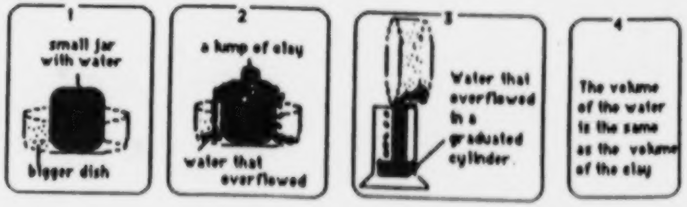
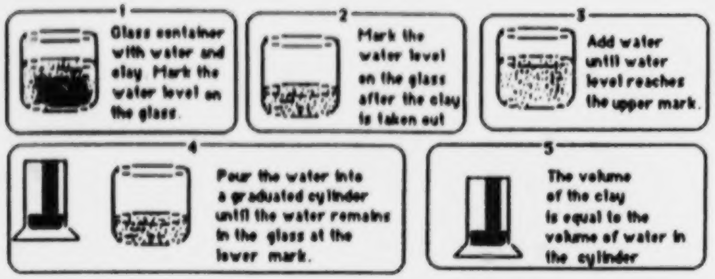

1
small jar with water
bigger dish
2
a lump of clay
water that overflowed
3
Water that overflowed in a graduated cylinder.
4
The volume of the water is the same as the volume of the clay

Figure 3.


1
Glass container with water and clay. Mark the water level on the glass.
2
Mark the water level on the glass after the clay is taken out
3
Add water until water level reaches the upper mark.
4
Pour the water into a graduated cylinder until the water remains in the glass at the lower mark.
5
The volume of the clay is equal to the volume of water in the cylinder

2. *Measure a lump of clay by transforming the clay into certain geometric solids.*

Let each student make a one cubic centimeter cube with the modeling clay. The cube will measure 1 cm by 1 cm by 1 cm and will have a volume of 1 cubic centimeter of 1 cc (also called one milliliter). If this sample is a little too small for the students to make and experiment with, let them make each side of the cube at least 2 centimeters—this would be an 8 cubic centimeter cube. After the students transform the lump of clay into a cube, have them measure the volume by width times length times height or base area times height. They should then measure the volume of the cube using the water displacement method and compare the results. Students can try measuring the volume of the lump of clay by transforming the clay into other geometric solids such as a rectangular prism (the formula is base area times height), a cylinder (the formula is base area times height), a cone or pyramid (the formula is base area times height divided by 3), or a sphere (the formula is 4/3 times *pi* times radius cubed).

3. *Why is the clay lighter in water than in the air?*

Give each group a weight scale with gram units. Let them measure the weight of their modeling clay and record the result in a chart that is drawn on the chalkboard or provided as a student worksheet (see Figure 4).

The data in the chart in Figure 4 was collected during actual class activities. The volume of the clay measured by the water displacement method is more accurate than the direct measuring method. To measure the weight of the clay in water, attach the clay to the hook of a spring scale and submerge the clay into water. Read the scale.

After the students complete the chart through hands-on activities, discuss the reason why the clay is lighter in water than in air. Inform them that 1 cc of cold water weighs 1 gram. Through this experiment the students will discover that 100 cc of clay submerged in water is equivalent to the water that is displaced. The difference between the weight of the clay in air and in water equals the weight of the displaced water. More than 2,000 years ago, Archimedes discovered this principle: An object submerged in water is pushed up with a force that equals the weight of the displaced water. This law is called Archimedes' Principle.

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Figure 4.

Group	Volume of the clay (cc)	Weight in air (g)	Weight in water (g)	The weight difference	The amount of water dis-placed
1	100 cc	155 g	55 g	100 g	100 cc
2	350 cc	543 g	193 g	350 g	350 cc
3	500 cc	775 g	275 g	500 g	500 cc
4	260 cc	403 g	143 g	260 g	260cc

By using the principle that the weight difference between an object in air and in water is exactly the same as the weight of the water that is displaced, students can solve the following types of problems:

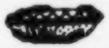
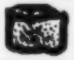
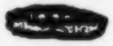
1. How many grams does a lump of clay weigh in water that has a volume of 1,000 cc but weighs 1,700 g in air?
2. How many grams does a rock weigh in water that has a volume of 5,000 cc and weighs 14 kg (14,000 g) in air?
3. What is the volume of a dog that weighs 40 kg (40,000 g) in air but 0 g in water?

Because the ratio between the weight of a lump of clay in air and the weight of an equal amount of water is constant, scientists discovered the specific gravity of substances. Specific gravity is found by dividing the weight of an object by the weight of an equal volume of water. The specific gravity of a substance is a number that tells how many times as dense the substance is as water. Some of the substances' specific gravities are: Water 1, the particular modeling clay 1.55, diamond 3.5, gold 19.3, ice 0.92, human body (lungs full of air) 1.07, copper 8.9, and oak-wood 0.85. These specific gravities are helpful to solve many mysterious problems. For example, if you question the purity of the 500 g gold bracelet, you can analyze the degree of purity by using specific gravity. The specific gravity of pure gold is 19.3. Let x be the same amount of water. Then $500 \div x = 19.3$. Then $x = 25.91$. Now, measure the volume of the bracelet. If the volume is equal to 25.91 cc then the bracelet is made of pure gold. If the bracelet is made of 450 grams of pure gold and 50 grams of copper, the total weight is 500 grams but the volume is 28.94 cc ($450 \div x = 19.3$, $x = 23.32$ and $50 \div y = 8.9$ and $y = 5.62$; $x + y = 28.94$). By this method, as the story goes, Archimedes solved the problem that his king asked him to solve. The problem was to find out whether the silversmith cheated or not when using a certain amount of gold to make a crown.

4. *Clay Boat.*

Let each group of students measure 100 cc of modeling clay and make a boat that floats in a bucket of water. Draw a chart on the chalkboard or provide a student worksheet (see Figure 5) and let each group of students measure and record the data in the chart. To measure the amount of water that is displaced by launching the boat, collect overflowing water with a large mouthed container and measure the amount of water in a graduated cylinder. Each group will discover that regardless of their shape, boats that weigh 155 grams will displace 155 cc of water, which is equal to the weight of the clay. See Figure 5 for examples.

Figure 5.

group	volume of clay	weight of clay in air	shape of boat	water displaced
1	100 cc	155 g		155 cc
2	100 cc	155 g		155 cc
3	100 cc	155 g		155 cc
4	100 cc	155 g		155 cc

Discuss the reason why a lump of clay with a volume of 100 cc displaces water of 100 cc when it is submerged in water, but the clay boat that is made of the clay displaces 155 cc, which is the same as the weight of the clay. Assist the students in discovering that: (a) in order to float, the volume of the boat must be greater than the volume of the water that is displaced; (b) the shape and size of the boat doesn't change the volume of water that is displaced; and (c) the weight of the water that is displaced is always the same as the weight of the clay.

5. *Loading cargo in the boat.*

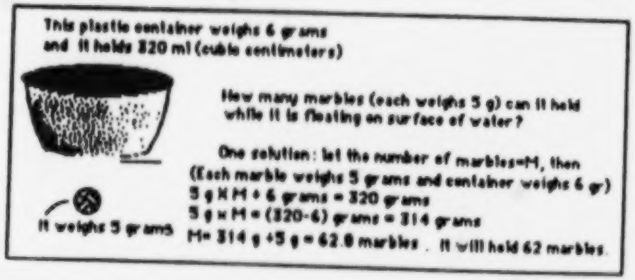
Let the students load marbles in the clay boats. Let the students reshape the boat without adding more clay so that the boat can carry as much as possible. Record the number of marbles that each boat carries on a chalkboard chart or student worksheet. This part is probably the most fun; the participating students rebuild their boat again and again. Find out the weight of each marble. (Weigh 10 or 100 marbles in a container and subtract the weight of the container, then divide by the number of marbles.) Convert the cargo weight of the marbles to grams.

After these activities, lead students to the concepts that: (a) the larger the volume of the boat, the more cargo it can load; and (b) the weight of the displaced water is always the same as the weight of the boat and its cargo. For example, if a boat weighs 155 grams and its cargo weighs 140 grams, the boat displaces 295 grams (which is 295 cubic centimeters) of water. Therefore, the volume of the boat must be larger than 295 cubic centimeters. This concept leads to the following predicting activities.

6. *How many marbles can a cup hold on the surface of water?*

Using thin plastic cups or paper cups, measure the weights and volumes. The volumes can be estimated by measuring the water that the cups hold using a graduated cylinder. Remind the students of the weight of each marble. With this data let each group predict how many marbles each container can hold on the surface of water. One example of the problem and its solution are illustrated in Figure 6.

Figure 6.


This plastic container weighs 6 grams
and it holds 320 ml (cubic centimeters)
How many marbles (each weighs 5 g) can it hold
while it is floating on surface of water?
One solution: let the number of marbles=M, then
(Each marble weighs 5 grams and container weighs 6 gr)
5 g X M + 6 grams = 320 grams
5 g x M = (320-6) grams = 314 grams
M= 314 g ÷5 g = 62.8 marbles . It will hold 62 marbles.
It weighs 5 grams

After each group makes their estimations, let them verify their guesses by placing marbles in the container one by one until it sinks. Before doing many estimations and verifications, the students may feel they are expert in solving these kinds of problems.

Evaluation:

Students will be evaluated while they perform the activities and projects.

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SSMILES

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A Graphing Activity:
Bottles
Grades 8-11

Mathematics Concepts/Processes	**Science Concepts/Processes**
volume and linear measurement, interpretation of data and graphs, model real-world phenomena with functions	observing, data collecting, hypothesizing, inferring, predicting, formulating and testing conjectures

Objectives

1. By pouring water into a bottle, students will be better able to gather data including the volume of water and the height in the bottle, make a table, and graph the data points on a Cartesian coordinate plane.
2. By making and interpreting a number of graphs, students will make conjectures about the relationship between the shape of the bottle and the graph.
3. By using a graph of the relationship between volume and height of water to describe the shape of a bottle, students will demonstrate their ability to read and interpret the graph of a function.

Rationale:

Developing a variety of strategies to solve nonroutine problems is a major goal for mathematics students in our secondary schools (National Council of Teachers of Mathematics, 1989). Two-dimensional graphing is one of the most important problem solving strategies for: (a) exploring problems and describing results, (b) making and evaluating mathematical conjectures and arguments, and (c) interpreting and evaluating mathematical ideas.

Evidence continues to mount in recent national assessments about student inability to either (a) apply mathematical knowledge in problem solving situations or (b) understand the structure underlying mathematical concepts and skills (Brown, Carpenter, Kouba, Lindquist, Silver, & Swafford, 1988). The following activity is designed to add to the mathematics teacher's repertoire of activities to strengthen student ability to explore, interpret, and communicate mathematical relationships (such as slope) using two-dimensional graphing.

Interrelationship of Processes and Concepts:

Collecting data and graphing, making conjectures, and testing those conjectures are basic processes in both mathematics and science. Students find this lab intriguing and eagerly accept the challenge to uncover the relationship between the bottle and its graph. This activity affords students both the opportunity to make graphs in which the value of one variable depends on the value of another and to interpret these data in a real world setting.

Content Background:

Students will need to be able to use rulers and graduated cylinders, make tables, plot points in the Cartesian coordinate plane, and interpret data from graphs. The activity is designed to be used near the beginning of a unit on linear equations or a unit on functions, but after students have learned to plot x and y coordinates on the Cartesian coordinate plane. In mathematics, this activity serves as a good introduction to slopes of functions. In science, this activity could be used during a unit on volume or at the beginning of the year during a discussion of the scientific method or on laboratory procedures.

Lesson Outline:

Time: Two 30-45 minute periods
Materials/Supplies:
For Total Class:
- Two brown bags each with one Mystery bottle inside, one of the bags has the graph of its bottle taped to the front
- 1 Student Summary Sheet per student

For Each Group of Three:
- 1 dishpan for holding all equipment in the lab
- 1 bottle (students will exchange for a bottle of a different shape after each experiment) (See Teacher Note 1.)
- Water (or a dry substitute) (See Teacher Note 5.)
- 1 beaker or container for holding water per group
- 1 centimeter ruler per group
- 1 graduated (ml) cylinder per group
- 1 Student Worksheet per group
- Graph paper
- Paper towels or a rag

Preparation:

Collect enough bottles to provide each group with more than one bottle. Students may help by bringing odd shaped bottles from home such as vases or food/pop containers. These bottles may be either glass or plastic, as long as they are clear. Be sure to allow a week to collect the bottles because they are often in use at home. Have students remove the labels and wash the containers before they bring them to school. In addition, flasks found in the chemistry lab will help round out your bottle collection.

Procedure:

1. Place numbered brown bags containing mystery bottles in the front of the room behind a screen, telling students that at the end of the experiment they will be able to:
    a. draw a graph after mystery bottle 1 is shown to them, and
    b. sketch mystery bottle 2 without looking at the bottle
2. Demonstrate the activity to the students including directions about safety and behavior. Using a sample bottle, pour water into the bottle using increments of 20 ml. After each 20 ml, measure the height of the water in centimeters. Have one student record the data at the overhead and a second student make the graph at the board. (See Teacher Notes 2, 3, and 4.)
3. Place the students in cooperative groups of three. Assign roles for each member of the group (equipment manager, data collector, and grapher). Tell students to change roles each time a new bottle is measured.
4. Teachers have the choice of handing out equipment and worksheets in a dishpan at student tables/desks or having student groups collect equipment and go to lab stations about the room.
5. During the lab, the teacher should probe each student for their conjectures about the relationships demonstrated in the lab.
6. Collect Student Worksheets after completion of the first set of activities (a minimum of three bottles).
7. Groups can complete the mystery bottle activity on the Student Summary Sheet either individually or in their groups at the teacher's discretion.
8. Following these activities, have individual students list their conjectures about the relationships between the bottles and their graphs on the Student Summary Sheet.

Evaluation:

Each group will collect data and make graphs. These should be sufficient to evaluate the first objective. The informal student interviews during the lab and the Student Summary Sheets following the lab will demonstrate each student's understanding of the underlying concepts described in the second and third objective.

Teacher Notes:

Note 1. The correspondence between the volume of the bottle and the measurement increments is important. It is suggested that the volume of the bottle range between 200 and 400 ml when full if you use increments of 20 ml.

This will provide between 10 and 20 data points. Less than 200 ml does not give enough detail and over 400 ml may take too long.

Note 2. It is suggested that one bottle shape be used by every student in order to establish the ability of the students to construct the volume by height graph.

Note 3. Initially, it is suggested that the height of the water in the bottle be used as the vertical axis of the graph.

Note 4. In order to draw the graphs, students may need assistance in determining appropriate scales on the *x* and *y* axis of the graph.

Note 5. The teacher may need to substitute a dry material such as rice or beans for use in the activity. In upper level science classes (10-11), the different units of liquid and dry measurements will need to be addressed.

Extensions:

1. Students may design a bottle by drawing its graph and challenge another student to draw the bottle.
2. Students may be asked to interpret graphs with other relationships.
3. Students may be challenged to make up a story about a relationship depicted in a graph.
4. See *Interpreting Graphs* by Sunburst Communications for computer activities aimed at the same objective as this lab.
5. This lesson can easily be modified for use in grades 5-8 (e.g., the focus could be directed more toward the understanding of *x*- and *y*-intercepts and intersections of lines).

References

Brown, C. A., Carpenter, T. P., Kouba, V. L., Lindquist, M. M., Silver, E. A., & Swafford, J. O. (1988, May). Secondary school results for the Fourth NAEP Mathematics Assessment: Algebra, geometry, mathematical methods, and attitudes. *Mathematics Teacher, 81*, 337-347.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

Student Worksheet

Cooperative Work Assignments: Fill in the names of the students who will complete each job during the activity. Each person will complete each task at least once.

	Bottle 1	Bottle 2	Bottle 3
Equipment Manager			
Data Collector			
Grapher			

The purpose of the activity is to find out the relationship between the volume of water poured into any bottle and the height of water in the bottle. At the end of the activity, you will be able to (a) sketch the graph given a bottle without taking data and (b) sketch the bottle given the graph.

1. a. First have the Equipment Manager collect all the materials including your first bottle. The Equipment Manager will pour 20 ml of water into the bottle. Then measure the height of the water in the bottle in centimeters.

b. Next have the Data Collector record the data on the table at the right.

V (ml)	h (cm)

c. In addition, have the Grapher draw a graph, label the axes, and graph the ordered pair.

d. Continue filling the bottle and measure the height of the water level every 20 ml until the bottle is full. The Data Collector and Grapher will continue recording and plotting the data.

e. Sketch the graph.

f. List your observatios and your conjectures about the volume of the water in the bottle in relationship to the height of the water in the bottle.

2. Repeat the above experiment with your second bottle. Remember to change roles.

V (ml)	h (cm)

3. Repeat the experiment with your third bottle. Again, remember to change roles.

V (ml)	h (cm)

4. Complete the following cooperative group checklist.

______ a. Did each member of the group participate equally in the experiment?
______ b. Can each of you sketch a graph of the volume of water in relationship to the height given a bottle?
______ c. Can each of you describe and draw a bottle given a graph of the volume of water in relationship to the height?
______ d. Can each of you list the general relationships found in this experiment?

Student Summary Sheet

Each student must complete this sheet individually.

1. Sketch the graph for Mystery Bottle 1. You may remove the bottle from the bag to look at it.

2. Sketch the Mystery Bottle 2 using only the graph on the outside of the bag. You may not peek!

3. List three generalizations about how you can predict the graph for any bottle.

SSMILES

Dennis Sunal and
Dyanne Tracy,
Department Editors

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The general format for a SSMILES idea is provided below. Of course some criteria are not always appropriate, depending on the SSMILES content.

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SSMILES Suggested Format
Title
Grade(s)

Mathematics Skills/Concepts:

Science Concepts/Processes:

Prerequisite Activities:

Objective(s):

Rationale:

Content background:
Explain mathematics and science background separately.

Interrelationship of content:
Explain how the mathematics and science content (concepts, skills, and processes) are interrelated.

Research background:
Briefly cite research and/or national association recommendations that provides readers a background on which the SSMILES can be couched.

Instructional model for activity:
Does the lesson involve concrete, pictorial representations, and abstractions? How does the learner participate in each of these levels?

Lesson Outline:

Time needed:
Materials/Supplies:
Preparation: List of preparations that must be made by the teacher before the lesson begins
Procedure: Sequence of lesson activities/questions to be asked by the teacher

Evaluation:

Techniques (especially non-paper-and-pencil) for determining whether students have achieved the lesson objectives

Teacher Notes:

Provision for special populations, extensions, hints, etc.

References and Resources:

Textual materials, software, supplier addresses, etc.

Submitted by:

Name
Institution
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Handouts:

Student materials (camera ready, if possible)

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SSMILES

Dennis Sunal and
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Department Editors

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Rusting Steel Wool
Grades 4-9

Mathematics Concepts/Skills

graphing, interpreting graphs, proportion, prediction, problem solving, volume measurement

Science Concepts/Processes

rusting, percent of oxygen in air, interpretation of data, space-time relationships, controlling variables, experimenting

Objectives:

By conducting hands-on activities, the students will be able to:

1. conduct a demonstration to find out the percent of oxygen in the air we breathe,
2. measure water columns using a millimeter ruler,
3. collect data and construct line graphs based on the data,
4. compute the proportional problem posed by the experiment, and
5. interpret collected data about rusting iron.

Rationale:

There is strong support for the integration of mathematics and science teaching and learning. The activities in this discovery-oriented lesson include process skills and concepts of mathematics and science. The hands-on activities of this lesson, to find out the percent of oxygen in air that we breathe, are not only motivating for intermediate grade students but also provide a chance to develop and apply science process skills to solve problems. Many extended lessons can be derived from this one.

Content Background:

About 21% of ordinary air is oxygen. As a chemical element, oxygen is needed to make most fuel burn and keep living things alive. About one-half of the Earth's geological make-up is oxygen, as is about one-half of the weight of most rocks and minerals. Rusting steel wool activities that demonstrate oxidation are simple and fun. Exposing steel wool to vinegar dramatically accelerates the rusting rate so that the students can detect and collect data within a typical instructional period. The vinegar, being acidic, furnishes hydrogen ions ($H+$) which pick up electrons from iron atoms to form transient neutral hydrogen atoms. Iron ions (Fe^{+2}) are then oxidized in the presence of water to form rust (Fe_2O_3) (Cotton, 1973, p. 516).

Lesson Outline:

Time: Two 45-minute periods

Student Work Group: This lesson can be sufficiently carried out with small groups of students.

Materials per Work Group:

three identical test tubes
a large-mouth jar that can hold three test tubes
steel wool
vinegar
a small jar
water
a ruler with millimeter units
a data collecting sheet (see Figure 2)
a graphing sheet (see Figure 3)

Procedure:

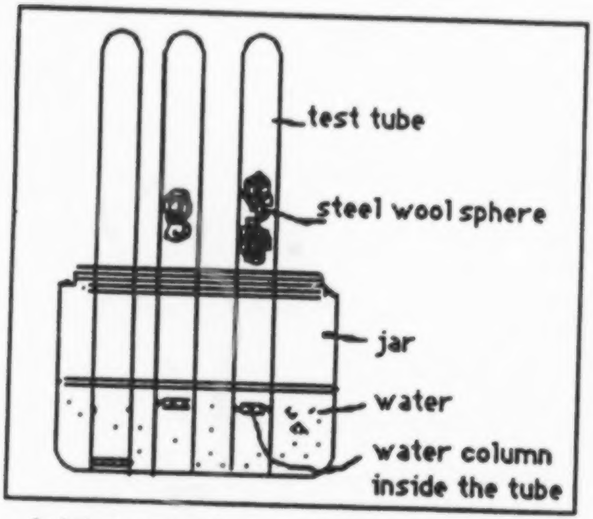
Have the students predict the percent of oxygen in the air we breathe, then inform them that they will form small groups and conduct an experiment to find out the actual percent. Divide the students depending on the availability of materials. Inform them that at the end of the unit, each group will submit a report for evaluation which will include: (a) statement for predictions of any change on the steel wool spheres as well as other initial predictions, water levels of the test tubes at the beginning of the unit, and check points for the prediction at the end of the unit; (b) observation records and measurement data similar to Figure 2; (c) graphs similar to Figure 3 and based on each group's data; (d) computation data for the percent of oxygen in air; and (e) a new question generated by each group for future experimentation.

Give each group three identical test tubes and a large-mouth jar that can hold them, a small jar for vinegar, a pad of steel wool, and a ruler with millimeter units. Explain to the students the tasks, procedures, and instructions that follow.

Make three identical steel wool spheres which are slightly larger in diameter than that of the test tubes so that the spheres do not fall down when inserted in the tubes. Form the sphere loosely, not squeezing the steel wool too tightly, so that air can reach all parts of the steel wool. Place the three spheres in a jar filled with enough vinegar to cover them. Keep the spheres submerged in the vinegar for about five minutes, as exposing steel wool to the vinegar dramatically accelerates the rusting rate.

Fill the large-mouth jar with about five centimeters of water. Remove the steel wool spheres from the vinegar and shake them in the air so that the steel wool does not hold vinegar drops inside the spheres. Because timing is an important variable of this experiment, designate three students in each group to perform the following activities as quickly as possible and at the same time. Using a pencil, one student pushes one steel wool sphere about half-way into a test tube; the second students pushes two steel wool spheres half-way into another test tube. The third student holds an empty test tube. The three students place the three test tubes in the jar of water so that the open ends of the tubes rest at the bottom of the jar (see Figure 1). Since the clean, wet steel wool will immediately absorb atmospheric oxygen, the test tubes should be placed in the jar of water immediately after the insertion of the spheres. This guarantees that the tube is full of average air rather than of oxygen depleted air when it is placed in the jar of water.

Figure 1.



Label the test tubes as "0-sphere test tube," "1-sphere test tube," and "2-sphere test tube." Lead students in making predictions about any changes of water level which may occur in the test tubes. Have the groups make predictions by answering questions such as: "What changes do you think will happen to the steel wool? What changes do you think will happen to the water level in the test tube? If any changes occur in the water levels in the various test tubes, how will the amount of the steel wool in each affect this?" Encourage students to make predictions without fear of making wrong predictions, by emphasizing that correct predictions will not have a greater point value than noncorrect predictions when the report is evaluated. Assign the students to observe and record any changes that occur; particularly to the water levels, moisture formation in the test tubes, and changes in color of the steel wool. Compare their predictions with their observations. Inform the groups that they will share their observations with the whole class later. Have each group measure the water columns for the three test tubes using millimeter rulers at five minute intervals for 35 minutes, and record the height of water columns as in Figure 2. A data collecting sheet similar to Figure 2 can be prepared and distributed to the students. By inserting a ruler in the water near the test tubes, students can measure the water column height in millimeters. The data in Figure 2 was recorded by an actual class.

Prepare a graphing sheet similar to Figure 3 and distribute to each student. Guide them in constructing line graphs using the data that each group collected.

Lead the students in sharing their observations and interpretations. The following five observations are common:

1. Immediately after placing the tubes in the water, the water level rose about 1 mm in all three tubes because of the difference between water and atmospheric air pressures.

2. More tiny water drops collected on the inside wall of the tubes containing steel wool spheres than on the walls of the empty tubes. The hydrogen ions that were furnished by the vinegar combined with the oxygen to form water which condensed on the inside wall of the test tube.

3. Some parts of the steel wool sphere changed in color becoming somewhat reddish. By combining with oxygen in the air, some of the iron changed into another substance called rust.

4. The water columns in the 2-sphere test tubes rose relatively faster than those of the 1-sphere test tubes. Two spheres of steel wool exposed more surface area to the air than the one sphere of steel wool. As a result, rust formed faster in the tube with two spheres during the 35-minute period. The oxygen in the trapped air changed into a solid form reducing its volume tremendously as the rust formed. Even though the resulting rust increases its volume by combining oxygen with its iron status, the increment is too small to be recognized. On the other hand, the volume changes caused by depleting the gaseous oxygen demonstrate that the relative volume is tremendously reduced when gas changes into a solid. This change causes the air pressure inside the tube to be lower. The higher atmospheric air pressure pushed water into the tube to achieve equilibrium between the air pressure inside and outside of the tube.

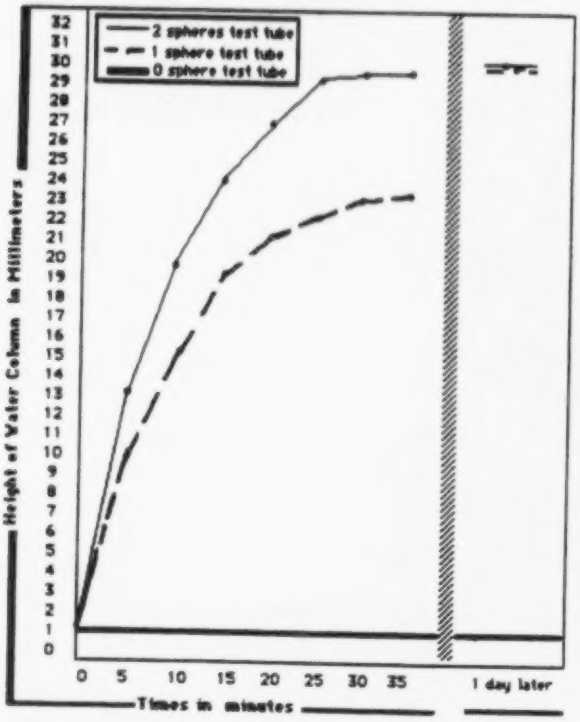
5. The water colum of the 0-sphere test tube did not change at all except for the initial 1 mm change.

Ask students to predict what would happen to the water columns between the 1-sphere and 2-sphere test

Figure 2. *Water level in the test tubes.*

Height of Water Column (mm)	Minutes	0	5	10	15	20	25	30	35	1 day later
	0 sphere T. tube	1	1	1	1	1	1	1	1	1
	1 sphere T. tube	1	10	15	19	21	22	23	23	30
	2 spheres T. tube	1	13	20	24	27	29	29	29	30

Figure 3. *Height of water column.*



tubes if they were to carry out the experiment until the following day. Point out to the students that the amount of oxygen in the trapped air inside each tube is almost the same and there is enough iron to rust. Have the students place their experiments in a corner of the room where they cannot be disturbed and check the result on the following day. The water columns between the two test tubes will be the same because the available oxygen in the tubes is about the same.

After the students discover that the water columns in the tubes with steel wool did not change because the oxygen was used up in the trapped air, ask the students to figure out the proportion of oxygen that was replaced by water in comparison to the volume of the air mass trapped in the test tube. The following method may be used to solve the problem. Encourage the use of calculators; however, this method is for approximation:

1. Measure the height of the water column inside the test tubes with steel wool spheres after one day. Measure the height of the air column inside the test tube that has no steel wool sphere. For example, these measurements were 30 mm and 144 mm respectively in an actual try.
2. Take out one steel wool sphere from the test tube and dry it off. Place the sphere back into a partially water-filled test tube to allow the student to measure the increase in the water level. In an actual try, the increased water column length was 0.5 mm. (Often students will be surprised by the small increment of the increased water level.) Subtract the measure of increased water level from the length of the air column. For example, the adjusted length of the air column of the test tube in our experiment was 143.5 mm.
3. The percent of the water column in comparison to the air column can be expressed in a proportion as 30 mm : 143.5 mm = ( )% : 100% and ( )% = 20.9%.

The result inferred is that about 21% of ordinary air is oxygen.

Many extended hands-on experiments can be derived from this exercise. Encourage students to generate new questions for future experiments and state the new question in the report. One interesting extension of the lesson is setting up the experiment with one test tube containing one steel wool sphere that was washed in water and a second test tube with one steel wool sphere that was washed in vinegar. The water level of the test tube containing the sphere washed in water will rise very slowly, while the water level in the test tube containing the sphere washed in vinegar will rise very rapidly. The vinegar (acid) reacts with the iron so that the iron is ready to oxidize relatively fast. Another variation of the lesson is setting up the experiment with one test tube with one steel wool sphere washed in motor oil and one test tube with a steel wool sphere washed in vinegar. A thin film of oil on the steel wool sphere washed in motor oil will prevent the contact of oxygen in the air, resulting in a very slow oxidation.

Evaluation:

Students will be evaluated on their ability to measure, record observations, share information, construct and interpret graphs, use problem-solving procedures, and interpret data. Using the assignment given at the beginning of the exercise, the students should be evaluated on the quality of the predications made, whether correct or incorrect; on their records of observations and measurements; on the graphs and the computation of the data for the percent of oxygen air; and on the additional questions they invent.

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SSMILES

Dennis W. Sunal and
Dyanne M. Tracy,
Department Editors

Submitted by:

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Will it Mix, Sink, or Float?
(Relative densities of liquids and solids)
Grades 6-9

Mathematics Concepts/Skills

geometry, graphing

Science Concepts/Processes

relative densities of solids and liquids; predicting, collecting, tabulating and interpreting data; measuring

Prerequisite Skills:

dividing whole numbers and decimals, reading a graduated cylinder, weighing objects on a balance, calculating volumes of regular-shaped objects, determining volumes of irregular-shaped objects, plotting and interpreting straight lines

Objectives:

The students will be able to:

1. predict what will happen to various liquids and solids if they are placed together in a container,
2. calculate densities of several liquids and solids and graph the mass and volume for each substance,
3. use mass and volume graphs of several liquids and solids to predict whether they will float, sink, or mix (for liquids),
4. test and revise predictions by actually pouring the liquids and placing the solids in the container, and
5. make a connection between measurement of density, graphical representation, and actual testing of the predictions

Rationale:

Density of a material is the mass of a given volume. Relative densities of selected liquids and solids can be calculated and checked by placing them in a container and observing their relative positions with respect to each other.

The points on the graph of mass/volume represent a constant ratio for a given material and are labeled as gm/cm^3 (for solids) and gm/ml (for liquids). This gives the slope of the line. Water has a density of 1 gm/ml. Liquids with higher densities sink, and those with lower densities float in water and form layers. Solids, when placed in a graduated cylinder containing layers of different liquids, will settle with respect to the liquids according to their relative densities.

Lesson Outline:

Time: three or four 45-minute periods

Materials/Supplies:

liquids—oil, dark corn syrup, water, and food coloring
solids—different geometric shapes and sizes (ice, wood, plastic, metals, glass, and cork)
250-500 ml graduated cylinders or equivalent balances (beam and/or spring)
centimeter rulers
thread

Preparation:

Each of the liquids—syrup, oil, and colored water—are placed in unmarked containers. Have available for each group of 3-4 students devices to measure mass, volume of liquids, and volume of regular and irregular-shaped objects.

Procedure:

Pour about 100 ml of blue water into a graduated cylinder or equivalent container. Challenge students to predict what will happen if you poured some brown liquid (syrup) into the container. Allow them to share their predictions and explanations. After the students have had the opportunity to discuss their ideas, slowly pour some of the brown liquid into the container. To the surprise of many students, it sinks to the bottom and forms a layer below the blue liquid. Before you do the same thing with the yellow liquid (oil), encourage students to come up with a logical way upon which they can base their predictions.

The volume of an irregular shaped object may be determined by attaching a sample to a string and lowering it into a container of water. The amount of water displaced is equal to the volume of the object.

Students may be given a written test where they are asked to calculate densities of several materials and solve problems involving equations and corresponding graphs. In addition, students may be evaluated based on their predictions, their performance during the laboratory activity, and their discussion.

Teacher Notes:

Density is defined as mass per unit volume and in metric unit of measurement, it carries the label of gm/cm^3 (for solids) and gm/ml (for liquids) (1 cm^3 = 1 ml). In plotting the density, mass is put on the vertical axis and volume on the horizontal. The reason for the departure in this activity, i.e., plotting volume/mass, is for students to see that the graph of denser material lies below the graph of a material with a lower density as appears in the container.

Many students believe that the amount of liquid makes a difference as to what happens when liquids are added to each other. They believe that a small piece of wood will float on a liquid, but a much larger piece of the same material will sink in the same liquid. In the case of liquids, students believe that a narrow layer of water, for example, will float on a layer of syrup, but a much thicker layer of water will sink, because there is more of it.

Such a belief may stem from the way the concept of density is presented in textbooks. For example, in some junior or senior high school textbooks, when talking about density, the terms used are *light* and *heavy*. Recently, a survey conducted by the author with a group of junior high school students revealed that many believed that a small piece of ice will float in the tub of water, but a block of ice will sink because it is too heavy.

The students are challenged to predict what will happen if some dark brown liquid (dark corn syrup) is poured in a 500 ml graduated cylinder or equivalent which contains about 100 ml of a blue liquid (water and food coloring). The students' responses can be interesting. Some think the thick brown liquid will mix with the blue liquid; others think that it will float on the blue water. Some may say that it will sink to the bottom of the blue liquid, and still others may believe that the liquids may react with each other.

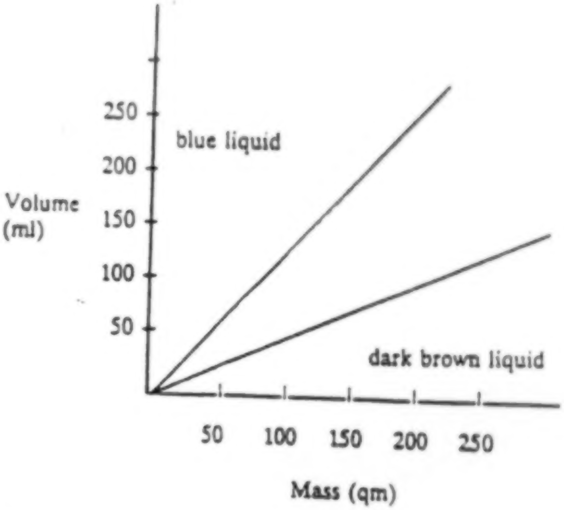
After they have had an opportunity to make predictions and discuss them, the students are asked if they can design an accurate way upon which they can base their predictions. Provide sample liquids, solids, and measuring devices for experimentation.

Students are encouraged, for the purpose of accuracy, to make several measurements at 50 ml, 100 ml, 150 ml, and 200 ml and to determine the corresponding masses of the liquids. Finally, the students plot the points for each of the two liquids (see Figure 1).

If the students determine the masses and the corresponding volumes for several points for the brown liquid and plot the graph, they will see that the graph (volume/mass) lies beneath the graph for the blue liquid. During the discussion, the students are asked to describe and compare the two graphs and argue how the graphs support, or do not support, their predictions. The teacher should take time to fully discuss the graphs (notice that we usually graph mass/volume). It is then time to let the students test their predictions.

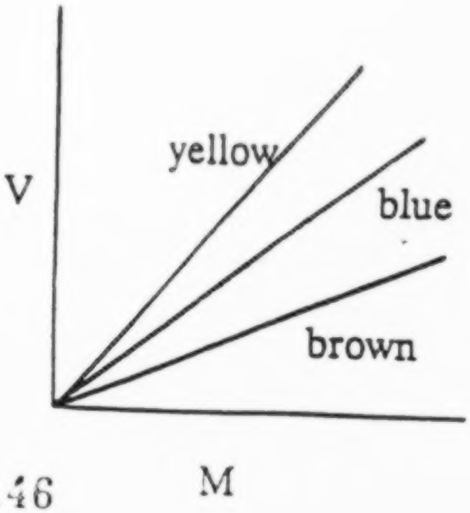
In small groups (cooperative learning groups are encouraged), each group can be given the materials and be asked to test their predictions after the discussion. Students will see that the brown liquid (syrup) does go to the bottom. Further, one can discuss the meaning of the phenomenon and help the students to connect their data to the graphs and their observations.

Figure 1.



The students will then be shown a yellow liquid (oil) and asked what they think will happen if it was poured into the graduated cylinder containing the blue liquid (water) and the brown liquid (dark corn syrup). They are encouraged to make similar measurements, i.e., mass/volume. If the students have determined their ratios accurately, they should obtain a graph which will lie above the graph for the blue liquid. Based on their graph and the previous discussion, the students are asked to predict what will happen. They then have the opportunity to test their predictions and find that the yellow liquid floats on top of the blue liquid (see Figure 2).

Figure 2.



The same procedure applies to solids. After the students have had the opportunity to investigate the liquids, they may be asked to predict what will happen if solids such as ice, wood, metal, glass, or cork are placed in the graduated cylinder containing the three liquids.

Hopefully, the students will suggest a procedure similar to that used with liquids. (They may need help with the volume measurements of the solids.) The solids may have the shapes of cubes, rectangular solids, cylinders, or spheres. (It is simpler if they have regular shaped objects.) One may ask the students to predict where a particular solid will rest in the graduated cylinder with respect to the three liquids.

Instead of presenting the students with all the solids, one may choose one of the materials, say, wood $D = 0.6$ g/cm^3. Encourage them to make several determinations of the shapes given, i.e., the ratio of mass over volume, plot the graph, and based on the data obtained, predict what would happen if they placed it in the graduated cylinder. They will discover that the graph for wood will lie between the graphs for the blue and yellow liquids. This implies that this particular wood will float on the blue liquid but will sink in the yellow liquid. They can then test their predictions by placing pieces of wood in the graduated cylinder containing the liquids.

What the students will soon discover, though difficult for most of them to believe, is that the size of the solid does not make a difference as to where the solid will lie with respect to layers of liquids. This also applies to liquids.

The integrated approach of science and mathematics to the concept of density illustrated in this activity combines prediction, activity, discussion, and graphical representation, and provides the student the opportunity to become self-reliant. One display tells the whole story (see Figure 3). This can be used as an illustration of how useful a graph can be. Figure 4 shows relative positions of liquids and solids in a container.

Extensions:

This activity has the potential to further study such concepts as slope and linear equations (in mathematics) and buoyancy and Archimedes principle (in science) using regular and irregular shaped objects.

Figure 3.

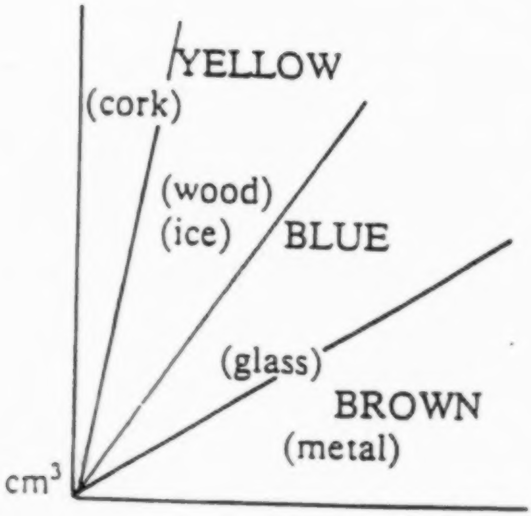
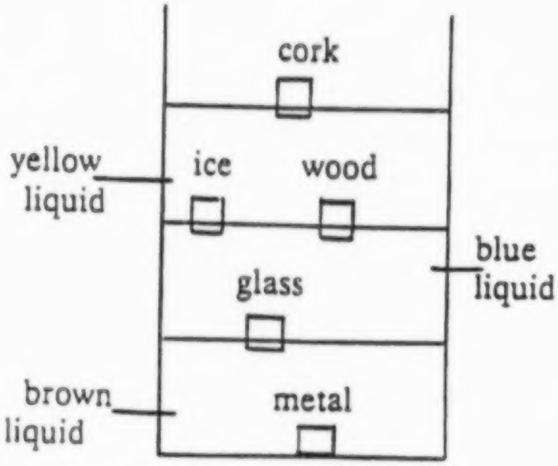


Figure 4.



SSMILES

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It's Not All Garbage!
Grades 5-8

Mathematics Concepts/Skills

bar and linear graphs, averaging, percentage, measuring, metric system, problem solving, scaling place value (metric conversion), fractional parts, sampling error, inferential statistics

Science Concepts/Processes

conservation, data collection, comparing, interpreting data, environmental awareness, prediction, forest ecology, trees

Objectives:

1. By determining the amount of wasted paper in their school, students will have the opportunity to see how their actions directly affect the environment.
2. By studying conservation, students will understand the importance of forests, trees, and the affect of deforestation on the earth.
3. By collecting data from everyday life and calculating percentages, students will apply mathematical skills to the real world.
4. By sampling the amount of trash wasted in classrooms, students will learn about inferential statistics.
5. Students will be introduced to the concept of scaling by creating graphs from collected data.

Rationale:

Interrelationship of Skills, Concepts and Society:

The application of mathematics and science makes learning real for students. In this activity, students will learn to make choices about the environment based on mathematical data collected from a real-life situation. Students will establish criteria outlining what constitutes wasted paper, calculate averages, and compute the number of whole or fractional parts of trees needed to produce a measured amount of wasted paper. Students learn mathematical concepts such as inferential statistics, scaling, and sampling error. They will learn to keep records indicating the amount of wasted paper and graph and interpret these results. After learning about the importance of trees in the world's ecology and by applying mathematical concepts in the collection and analysis of data, students will have a better understanding of how their life style affects the environment.

Content Overview:

Science:

When students are given the fact that one average tree yields about 118 lbs (54 kg) of paper or that it takes 17 trees to make a ton (909 kg) of paper they have the opportunity to see how, as individuals, they can affect their environment (Balian, 1988). By collecting wasted paper out of classroom trash cans and weighing it, students will compute how many trees each classroom wastes in a given amount of time. This project offers children the opportunity to learn the obvious facts about trees as well as how they are important to humankind. Some facts you might want to share:

1. Trees help remove carbon dioxide from the atmosphere and release oxygen in its place. Each tree consumes approximately 13 lbs (6 kg) of carbon dioxide per year. The amount of deforestation around the world has therefore contributed to the 25% increase of carbon dioxide in the atmosphere. This affects the climate of the world by increasing the temperature of the planet (Earthworks Group, 1989).
2. It takes a tree 15-20 years old to make enought paper for 700 grocery bags (Earthworks Group, 1989).
3. The average American uses 580 lbs (264 kg) of paper per year (Earthworks Group, 1989).

4. Amazonian forests produce 40% of the world's oxygen. Deforestation has reduced this percent.

5. Deforestation contributes between 10-30% of worldwide carbon dioxide emissions to the atomosphere (Earthworks Group, 1989).

6. Recycling paper uses 64% less energy than manufacturing from wood pulp (Holm-Shuett & Shuett, 1990).

Some facts which might help children understand why trees are useful to humankind are the following:

1. One tree releases enough oxygen in 24 hours to help you stay alive for that same length of time (Balian, 1988).

2. Trees provide food, shelter, and homes for many birds and animals (Braus, 1988).

3. Trees lower air temperatures through evaporation and help increase humidity (Balian, 1988).

4. Trees help prevent soil erosion (Braus, 1988).

5. The leaf surfaces of trees help filter out pollen and other irritants out of the air (Balian, 1988).

Mathematics:

This activity affords the opportunity to teach several mathematical concepts related to sampling, making statistical inferences, and the reporting and interpretation of data. For example, it would take too long to gather data from trash for the whole year (students would lose interest). Instead, a typical week is selected to take a sample of the trash for a few days and make inferences about the whole year from the data. A discussion of sampling bias should be done with the students. For example, if students in other classes were aware of the environmental study of trash, then they may change their behavior for the week (or teachers may institute a change so as not to look bad). Different teams of students gathering trash may be inconsistent with their selection of what constitutes a waste of paper (some students may simply want to gather the most). The closer the sample week is to the typical week, the more generalizable are the results.

In addition, care needs to be taken in reporting the data. For graphic displays, an appropriate scale needs to be selected so that visual interpretations are clearly communicated. A good rule of thumb for labelling tick marks would be to estimate the minimum and maximum expected number of grams of wasted paper (this can come from the trial week used as a baseline), and then divide the difference (max-min) by 10.

Lesson Outline:

Time: Minimum three 30-45 minute periods; ongoing if desired once/week

Materials/Supplies:

tag board for making graphs, marking pens, calculator, thrown away binder paper, discarded (clean) paper products, graph paper

Preparation:

Students will be collecting trash cans from other classrooms and need to understand that they should use gloves and should only remove thrown out binder paper or other clean paper products from the trash. Facial tissues are to be left in the trash. Wasted paper can be defined as those papers which have just a few marks on them or those which were not completely written on. For example, a short assignment should be done on half a sheet of paper not a full sheet. Students will make the decision on their criteria for wasted paper. Before children actually go into classrooms, be sure to check with the classroom teachers for permission, and let the teachers know the time your children will be in to collect the waste paper

While making discoveries about their environment, students can use mathematics skills at a level which easily suits them. Eighth graders can, for example, determine how many times they have to collect trash cans so that they are statistically accurate in their extrapolations. A trial run with a small number of trash cans may help in this decision. Some children could count the number of pieces of wasted paper and determine what part of the school would this paper cover or figure out how many pieces of paper would wallpaper the classroom.

Several different bar graphs can be made for each classroom. They could show the actual number of grams of wasted paper or the percent of wasted paper so that students can determine if there has been any improvement. A line graph of the combined classrooms can be a third graph.

The teacher should have books, pamphlets, and other visual aids to help students understand the importance of trees and some facts about trees.

Procedure:

The class will be working in cooperative groups. Possible jobs for each member of the group are: (a) waste paper collectors, (b) forest ecology researchers, (c) graph makers, and (d) waste paper measurement. Expert groups could be set up so that the research group shares all learned information with each other; the graphing group can compare graphs and form generalizations; the measuring group can share problems and proper techniques; and the collectors can report classroom attitudes and discussions brought up in their respective assigned classrooms. Each group will be responsible for making graphs using data from their assigned classroom, keeping the students in their assigned classroom informed of their progress, learning about trees and conservation, and understanding all mathematical concepts presented.

1. The class will decide on criteria for wasted paper. Have students discuss this issue in their groups first, then come to a class descision so that all are using the same criteria. Each group will need to discuss what needs to be done and divide the work among themselves according to the description above. One, for example, will collect the trash cans; one or two will prepare graphs, etc.

2. A group of students (depends on class size and number of classes participating) are assigned to collect paper from each participating classroom. It is the students' responsibility to talk to their assigned class and inform them of the importance of wasting paper, etc. and to keep them apprised of how well they are conserving paper. Discussions with their assigned classrooms are encouraged.

3. The trash cans are brought back to class, and the paper which should not have been thrown away, according to class criteria, is separated from trash and weighed in grams and converted to kilograms. Some students should check the weighing to make sure it is accurate.

4. The students graph their results on heavy tagboard for each classroom and bring it back to their assigned classroom. It is hung where all students can see it until paper is collected the next time and new information is added to the graph. Students are given instruction in scaling so that they make proper graphs that are meaningful.

5. Each group is presented with the problem, "How many sheets of paper make up a gram? kilogram?" They are to collect data to show this. All groups will compare data. What statement can they make about the number of sheets of paper needed to make up a gram? Hopefully, they will realize that different papers may have different results. Can this information be applied in some useful way? Do they have to weigh the paper each time? Can they devise a way to test their weighing accuracy?

6. After the last paper collection, the average kilograms of paper wasted per classroom is calculated. What is the average amount of paper wasted for the whole school? What percent of all trash is wasted paper goods? This data is collected, and the yearly waste is estimated based on this data. This data can be used as a basis for teaching sampling error and inferential statistics so that students have a firm understanding of the sampling process.

7. The number of trees used for the wasted amount of paper is then calulated. Students can be told how much paper an average tree produces or they can research this themselves.

Evaluation:

Students' attitudes about throwing good paper away will demostrate understanding of the first objective. The accuracy of their graphs and all calcuations will indicate understanding of the mathematic skills needed to complete this activity. The following types of questions can be asked to evaluate mathematical concepts:

1. How many grams of paper are wasted if there are 1.5 kg of wasted paper in a trash can?

2. If all the paper in a trash can weighed 75 g, what percent of paper was wasted if there was 25 g of paper in the trash which should not have been there?

3. What scale would you use on your graph if the highest amount of paper wasted was 125 g and the lowest was 25 g for all classrooms?

4. How close did your group (class) come to identifying typical classroom paper wasting? What would you do differently in sampling trash cans? How widely can you generalize your results?

Extensions:

1. Have students write a paper about why trees are important to them and/or a values paper in which they write about whether or not they have learned to value natural resources. Why or why not? What can they do, as an individual, to conserve trees?

2. Students can learn how to do library research by thoroughly investigating the importance of trees and forests.

3. Students can extend this project to junk mail that the average American family receives each day.

4. A school bulletin board can be set up so that the whole school can see the school's progress after each collection.

5. Students can write letters to appropriate politicians urging them to support bills which protect our trees.

6. If the teacher has been trained in *Project Learning Tree*, an environmental awareness program, he or she can do several of the activities with students.

7. Students can learn to recycle newspaper and/or clean paper from the trash. This paper can be used to make Valentine Day cards, art projects, or stationery.

8. Students can expand computations beyond their school by determining the number of schools in the district, county, state, and even across the United States to determine the number of trees that could be saved every day.

9. Students can make posters depicting the importance of trees.

10. Students can network with other schools using computers or other methods of keeping in touch to compare the amount of paper in their respective schools. They can, together, find ways to help save paper in their communities and schools.

11. Mathematical concepts can be extended to include precision of measurement to determine possible error of the massings of the wasted paper.

12. Students could determine whether the mean, median, or mode best describes the typical classroom paper waste.

13. Have students organize the planting of trees within their school or community.

14. Older students can mathematically determine the number of samples needed to do a state-wide study of paper wasted in schools.

15. The concept of sampling can be extended to the study of other conservation areas such as total garbage wasted.

16. Students can determine the percent of food thrown away each day in the cafeteria.

Student Data Collection Sheet
It's Not All Garbage

1. The teacher will assign you to a classroom. You will go into the classroom and ask permission of that teacher to talk to the students. You are to explain that:

a. You are trying to find out how many trees the school uses per day.

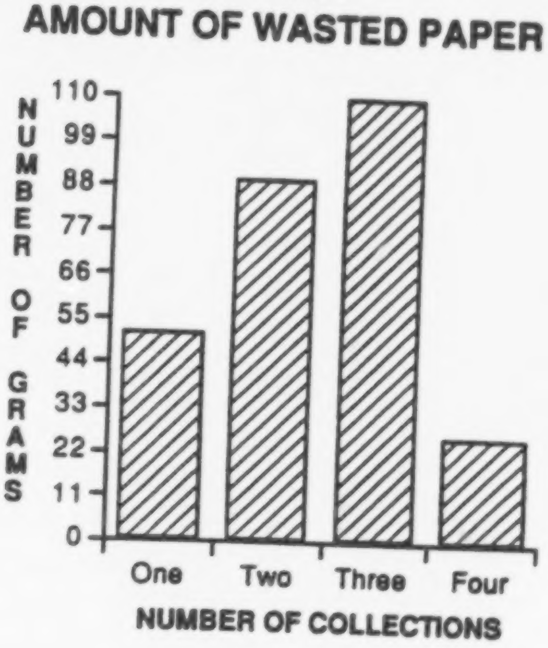
b. You will be collecting trash cans and separating paper which should be thrown away from paper which still could be used to see how much paper is being wasted.

c. Your class will weigh the paper and see how many trees or parts of a tree the school wasted that day. It takes 17 trees to make a ton of paper.

d. You will come into the classroom several times to pick up the trash can and that you will inform the class each time how well they are doing. Every class which improves will be given a certificate to show that they are good conservationists. The teachers in your assigned classroom will not know when you are going to pick up the waste paper because you will pick it up at different times of day or different days each week.

2. You will keep track of how much paper is wasted in you assigned classroom by making a bar graph each time you collect a trash can. The graph will look something like this:

Figure 1. *Amount of wasted paper.*



Answer the following questions using all the classroom graphs or by using your individual graph.

1. Which teacher's class wasted the least amount of paper? How can you tell this is true?

2. Using the data you collected from your assigned classroom, determine how many kilograms were wasted in all the collections from that classroom. How many for all the classrooms in which trash were collected?

3. Did your assigned classroom waste less paper each time you collected their trash? If not, what can the class do to decrease the amount of wasted paper?

4. Using data from all collections in the school, determine how many trees your school has wasted during the time of this project.

5. Make a line graph showing data from all the classes in which trash cans were collected. If you were going to continue collecting trash, can you predict the average amount of wasted paper which might be collected?

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SSMILES

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Measurement: The Human Body
Grades 7-12

Mathematics Concepts/Skills

addition, multiplication, decimals, mean, rounding, metric measuring, estimating, ratio, patterns, equations, use of a calculator

Science Concepts/Skills

metric measuring, predicting, data collecting, variation in nature, growth, patterns, skeletal system, physical model, mathematical models, sampling, bones of the body

Objectives:

1. Students will estimate and measure in metric units the head length, foot length, arm span, and standing height (stature) of a partner.
2. Students will measure the approximate lengths of the humerus, radius, femur, and tibia in living humans.
3. Students will examine patterns in collected data.
4. Students will use a set of equations to predict stature from bone lengths and compare results to other samples of humans.

Background:

During a unit on bones and their function in providing the skeletal support of the body, the protection of vital organs, and the framework for muscle attachment, capitalize on students' interest in the exploits of Indiana Jones. Archaeologists' and physical anthropologists' examination of unearthed, human bones to determine, among other things, the age at death, sex, stature during life, and possible cause of death of the individual can serve as a basis for students to collect data about parts of the human body, to analyze the data for patterns, and to consider the role of mathematical models in our understanding of natural phenomena. Such activities are consistent with the recommendations contained in the National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics* (1989) which suggests that students be provided with opportunities to apply mathematics in a variety of contexts, to other curriculum areas, and to daily life. Moreover, students are using concrete materials, the human body, to collect meaningful data that will be used symbolically in the form of sets of equations to search for patterns in nature.

Lesson Outline:

Time: two or three 45-minute periods

Materials/Supplies:

centimeter rulers/measuring tapes
calculators
model of human skeleton (bone or plastic)
computer/spreadsheet program (optional)
full-length photographs of individuals (optional)

Preparation:

Handouts of equations for stature prediction; sample bone length/stature data for Activity 2, Parts 2 and 3 (these data are needed only if the teacher decides not to have students collect their own data).

Procedure:

Before students measure and search for patterns involving human bones which they will not be able to see, have them predict, measure, and look for patterns between external body parts (head, arm, foot, stature).

Activity 1

1. Students should work in pairs and record their own data (see Table 1).
2. Partners will estimate each other's head length (chin to top of head) and then measure using a metric ruler (to the nearest .1 cm).
3. Repeat Step 2 with foot length (back of heel to tip of longest toe), arm span (tip of middle finger to tip of middle finger), and stature.
4. Students will calculate, from their data, their head length to stature ratio. Students will round measurements to obtain ratios like 1:6, 1:7, etc. and them generate decimals with the aid

of a calculator.

5. Repeat Step 4 by having students compute a foot length to stature ratio and an arm span to stature ratio.

6. As students complete their calculations, have them record their ratios on the chalkboard, the overhead, or on a spreadsheet. Use three columns, one for each ratio.

7. As a class, look for patterns within each set of ratios. Ask speculative questions like, "I wonder what the head length to stature ratio would be for newborns? for adults? Why am I able to determine the head length to stature ratio for an individual that I cannot measure but who is pictured in a photograph?"

8. Conclude the activity by wondering aloud whether or not patterns exist between the measurements of the bones of the body that the students have been studying. This question will be the focus of the subsequent activity.

Table 1

Estimated and Actual Body Measurements and Ratios

	Head Length	Foot Length	Arm Span	Stature
Estimate (cm)				
Measurement (cm)				
Calculated Head Length/Stature Ratio (from measurements)				
Calculated Foot Length/Stature Ratio (from measurements)				
Calculated Arm Span/Stature Ratio (from measurements)				

Activity 2

1. Use a human skeleton (bone or plastic) and locate the humerus, radius, femur, and tibia. Students should locate each of the bones on a diagram and then on themselves.

2. Again working with a partner, let each student measure in centimeters the partner's four bones with a metric ruler and record the measurements. Students may refer to the classroom skeleton to estimate the end points of the bones.

3. As an out-of-class assignment, each student will measure in centimeters and record the lengths of the humerus, radius, femur, and tibia on the right side for one or more adults (age 21 or older), being sure to note the sex of each subject. A diagram of the skeleton can be used to help students estimate the end points of each of the bones. The students should also measure each subject's stature. (Note: Teacher-supplied data can be used for Steps 2 and 3 to save time or to eliminate any potential problems with data collection.)

4. Collate the data on the chalkboard, overhead, or spreadsheet and have students look for patterns. For example, is one of the four bones always longer than the other three? How about the length of arm bones versus leg bones? Are there differences between males' and females'? Potential difficulties in bone lengths accurately locating the end points of the bones can be identified as a source of error. (Most bone length measurements reported in the literature are determined from skeletons.) Be sure to use this opportunity to stress variation in nature. The function of each of the bones can also be discussed.

5. Next give the students the following two sets of equations from Dupertius and Hadden (1951). These equations are general and not race specific and are adequate for the purposes of these activities. Specific equations for given races can be obtained from Dupertius and Hadden's original work or from Bass (1971). Using the appropriate set of equations and a calculator, compute a value for each equation for each subject measured in Steps 2 and 3.

Male Subject

1. 2.97 x length of humerus + 73.6 cm
2. 3.65 x length of radius + 80.4 cm
3. 2.24 x length of femur + 69.1 cm
4. 2.39 x length of tibia + 81.7 cm
5. 1.23 x (length of femur + length of tibia) + 69.3 cm
6. 1.73 x (length of humerus + length of radius) + 71.4 cm
7. 1.42 x length of femur + 1.06 x length of tibia + 66.5 cm
8. 1.79 x length of humerus + 1.84 x length of radius + 66.4 cm
9. 1.93 x length of femur + .57 x length of humerus + 64.5 cm
10. 2.10 x length of tibia + .61 x length of radius + 78.3 cm
11. 1.44 x length of femur + .93 x length of tibia + .083 x length of humerus + .48 length of radius + 56.0 cm

Female Subject

1. 3.14 x length of humerus + 65.0 cm
2. 3.88 x length of radius + 73.5 cm
3. 2.32 x length of femur + 61.4 cm
4. 2.53 x length of tibia + 72.6 cm
5. 1.23 x (length of femur + length of tibia) + 65.2 cm
6. 1.98 x (length of humerus + length of radius) + 55.7 cm
7. 1.66 x length of femur + .88 x length of tibia + 59.3 cm
8. 2.16 x length of humerus + 1.53 x length of radius + 57.6 cm
9. 2.01 x length of femur + .57 x length of humerus + 57.6 cm
10. 2.08 x length of tibia + 1.06 x length of radius + 65.4 cm
11. 1.54 x length of femur + .76 x length of tibia + .13 length of humerus + .30 x length of radius + 57.5 cm

6. After students have calculated all 11 values for a subject have them average these values and examine the resulting mean. This mean will be an estimate of the subject's stature.

as will the calculated value from each of the 11 equations. Students can compare these values to the actual measured stature of the subject.

7. Ask students if they think using one bone measurement (e.g. the humerus) and one equation or 4 bone measurements and 11 equations would be a more accurate model. Why?

8. Encourage students to consider possible sources of error in the activity.

9. Have students predict how accurate this set of equations would be for their own body measurements or for measurements from elementary school children.

10. How were these sets of equations developed? Why is there a different set for males and females? Would different sets be expected for people from different cultures? Why? Why not?

To extend students' reflection on these last three questions, assign groups of students one of the following activities.

Extensions:

1. Students may investigate alternative sets of equations that have been developed for the estimation of stature during life. Krogman (1962) presents some of the historical development from the 1890s to the 1950s with several different sets of regression equations noted. Also, have students consider how the equations were developed, the nature and size of the samples, and the procedures and instruments for measuring the bones. How does one decide which set of equations to use?

2. Have students locate data to compare stature from different cultures and within a culture over a period of years. Current data can be collected and compared to that from the 1950s for 8 year olds (Meredith, 1969a), and to data for 13 year old girls and for 15 year old boys (Meredith, 1969b).

3. In addition to bone length, what other types of data do physical anthropologists use to determine age at death, sex, race, and stature during life of skeletal remains? If students are interested in determining as much as they can from a classroom skeleton, consult the suggested activities by Borst (1986).

4. Finally, have a group of students write a computer program or set up a spreadsheet to calculate stature estimates after the user has entered bone lengths. Alternatively, write a program where the stature of an individual (e.g., the school principal or media center specialist) is entered and estimates of bone lengths are displayed.

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SSMILES

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Super Sand Sifting
(Sieving Different Size Fractions of Sediments)
Grades 3-4

Mathematics Concepts/Skills

greater than/less than, ordered series, measuring diameter of a sphere

Science Concepts/Skills

classification, observation, sediment particle size, current strength, sedimentary rocks, measurement of volume

Prerequisite Skills:

measuring with a graduated cylinder; identifying the diameter of a sphere; familiarity with rocks; addition, subtraction, and fractions

Objectives:

Science

The students will be able to:

1. separate different sized portions of materials by sieving,
2. classify sediments by particle size,
3. identify different particle sizes by appropriate terms, and
4. infer that sediments from different places and environments are composed of different proportions of the various sizes of particles.

Mathematics

The students will be able to:

1. apply the greater than/less than concept to sieving of particles (A sieve separates particles larger in size than the sieve holes from those that are smaller and can fit through the holes),
2. form an ordered series of particles by size,
3. use addition to check their sorting, and
4. use a graduated cylinder to mesure volume.

Rationale:

This activity gives the student the opportunity to practice important science process skills of observation, classification, and measurement. The science content of this lesson could be used with an earth science unit on weathering, erosion, streams, sedimentation, sedimentary rocks, soils, beaches, dunes, or glacial deposits. The mathematics content of this lesson connects number lines, ordinal numbers, greater than/less than, and fractions.

Background:

Many sedimentary rocks are composed of weathered particles that were transported and deposited by wind, water or ice. These rocks are termed detrital sedimentary rocks. Particle size is the primary basis for classifying these rocks because particle size provides information about the environment of deposition of the sediment (see Table 1). Air and water currents sort sediments by size--the stronger the current, the larger the particle a current is able to carry. Swiftly flowing rivers, landslides, and glaciers are able to transport gravels. Windblown dunes, most beaches, and some stream deposits are composed of sand because less energy is needed to transport these smaller particles. Muds are generally found in the quiet waters of lakes, lagoons, the ocean bottom, and swamps. Clays settle very slowly and require a low energy environment for deposition.

Students can determine particle sizes of loose sediments by sieving. A sieve with 2 mm holes will separate gravels from smaller sediments. A sieve with holes that are 0.0625 mm will then separate the sand from mud. In this way, particle size is rapidly and easily determined and sediments are easily classified. Extra sieves can be used to separate granules, coarse sand, and fine sand.

It is best to start out sieving with more familiar and regular particles. Beads, cereals, and seeds are good materials. These can be color coded so that students recognize the different size components of the mixture more readily. A table of various common particles of varied sizes is provided below (see Table 2).

Table 1

Sedimentary Particle Sizes

Size Range (mm)	Particle Name	Common Sediment Name	Detrital Rock Name	Common Depositional Environment
>256	boulder		if rounded	landslide
64-256	cobble		particles,	
32-64	very coarse pebble	gravel	conglomerate	or river
16-32	coarse pebble		or	
8-16	medium pebble		if angular	or glacial
4-8	fine pebble		particles,	
2-4	granule		breccia	
1-2	very coarse sand			stream
0.5-1	coarse sand			
0.25-0.5	medium sand	sand	sandstone	or beach
0.13-0.25	fine sand			
0.063-0.13	very fine sand			or dune
0.0039-0.063	silt		shale	lake
<0.0039	clay	mud	or siltstone	or lagoon
			or mudstone	or marsh
				or ocean bottom

The National Science Teachers Association (NSTA) (1990) recommends that mathematics be integrated with science. Sorting items by size and forming a series of size-graded categories and concepts of greater than (the sieve holes) and less than (the sieve holes) are mathematical concepts related to classification of sediments by particle size. The NSTA also recommends that activities involve manipulation of equipment and student thinking about the activity. This lesson provides concrete, hands-on experience in separating and classifying particles by size using sieves.

Learning Cycle Lesson Outline:

Time: approximately two 45-minute class periods

Materials for Exploration Phase:

spherical beads of various sizes such as 500 ml of macrame beads (about 1.5 to 3.0 cm in diameter), 500 ml of pony beads, 500 ml of Indian seed beads (Various other items can be used instead of beads - [see Table 2]. Using cereal such as Kix or Cheerios, dry grits, and granulated sugar might be a more economical approach.)

containers of dry sediments such as 100 ml of mixed up gravels, sands, and mud for each group (sediments must be dry and mud must be broken up into a powder--no clumps)

one graduated cylinder for each group

three 500 ml beakers

several bowls or pans for each group

a set of several sieves of different sizes; the holes in each sieve must all be the size diameter and should be either square or circular. Sieves can be obtained in many ways:

1. Purchase children's toy sand sifting sieves.
2. Use colanders and kitchen strainers from home.
3. Use green plastic baskets that cherry tomatoes or strawberries are packed in (close off holes on the sides with wide tape).
4. Use the shaker top jar that spices or cake decorations come in.
5. Construct sieves from inexpensive plastic containers (margarine tubs, ice cream buckets, whipped topping containers). Punch or drill holes in the bottom or cut a few larger holes and cover with netting and hot glue around the edges. Netting with holes of various sizes can be purchased at a fabric store. Net bags from onions, oranges, and potatoes can also be used.
6. Nylon pantyhose, cheese cloth, or fabric can be stretched across the mouth of a mason jar with a screw-on lid (no liner).
7. Make simple wooden boxes without tops or bottoms and carefully staple window screening of various meshes across the bottom of the boxes, or use pegboard as a bottom.

Table 2

Common Particles of Various Sizes

Particle Size Term and Diameter (mm)	Common Example
boulder >256	weather balloon beach ball
cobble 64-256	basketball soccer ball cantaloupe orange baseball
very coarse pebble 32-64	golf ball plastic Easter egg Oreo cookie lid from milk jug
coarse pebble 16-32	high bounce toy balls coins
medium pebble 8-16	Cheerios marbles M&Ms standard shirt buttons
fine pebble 4-8	large pearl tapioca whole dry soy beans Tart 'n' Tiny candies BBs
granule 2-4	bird seed mustard seed Indian seed beads
very coarse sand 1-2	sesame seeds dry quick grits dry tapioca
coarse sand 0.5-1	celery seed poppy seed
medium sand 0.25-0.5	corn meal
fine sand 0.125-0.25	granulated sugar table salt
very fine sand 0.065-0.125	ground nutmeg flour
silt and clay <0.065	powdered sugar corn starch

Materials for Invention Phase:

spherical items of different sizes, about six for each group, such as sports balls, fruit, marbles, beads, rock cobbles and pebbles, dry cereal, and beans

pictures of environments of deposition such as dunes and waves at seashore, glacier, flood waters, streams, dessert sand dunes, landslide areas, etc.

various sedimentary rocks such as conglomerates, sandstones, and shales

Materials for Expansion Phase:

containers of natural sediments from different environments

Preparation:

Have three buckets of particles ready in advance. See Table 2 for ideas. Each bucket should have particles all the same size but a different size than the particles in the other two buckets.

Mix up a 100 ml beaker of sediment for each group to sort. It should have at least three different sizes of sediment in it. The sediment must be loose and dry.

Procedure:

Exploration. Divide the children into small groups. Start out by mixing up a batch of beads in front of the class. Measure out 500 ml of large (coarse pebble-sized) macrame beads into a bucket. Add 500 m of (fine pebble-sized) beads. Measure 500 ml of (granule-sized) Indian seed beads and add this. Mix the beads thoroughly. Measure these beads by scooping up a 500 ml beaker full of beads. You may want to use beads of the same color for each size.

Ask the children if they can think of a fast way to separate the beads. Discuss the suggestions.

Divide the bucket of beads up into enough portions so that each group gets part. Give each group a set of two sieves. Choose the sieves so that macrame beads will be caught in the pan of the coarsest sieve but all other beads will be able to pass through the holes. The second sieve should have holes that the Indian seed beads can pass through but not the intermediate size beads. Let the students experiment until they are able to separate the three sizes of beads.

Have students report how they were able to separate the beads. Let students use a graduated cylinder to measure the volume of each size of beads that they have separated. Groups can report their findings. Students can add up the amounts of the three different sized beads. Sums should add up to approximately 500 ml each. Discuss how errors may have occurred.

Now produce jars of 100 ml of mixed up sediment. (In advance, the teacher will have prepared the sediment mixtures by measuring out different amounts of gravel, sand, and dry mud into the containers.) Each group should now have a set of at least three different sieves. The first sieve should separate pebbles (pebbles are too large to fit through the holes but granules and everything else will), the second sieve should catch the granules but let the sand and clay through, and the third sieve should retain the sand but let the silt and clay through. Depending upon what sieves the teacher has available, different particle sizes can be separated.

Tell the class to experiment with the sieves and see if they can separate out different sized portions of the sample (geologists call these different sized portions size fractions). Tell them to measure the volume of each portion and record their results. Have groups report their results in oral and chart form. Ask students to describe situations in which sieves would be used (straining juice; draining spaghetti or berries; sorting crushed ore in a refinery; sorting lead shot, ball bearings in a factory; etc.).

Progress Assessment:

Evaluate the students on how well they were able to completely separate the three components. Ask questions such as, "If you wanted to separate gravel from sand, what diameter should the holes in your sieve be?"

Invention.

1. Explain to the class that many sediments are made up of particles of a variety of different sizes. Tell the class that particles of certain sizes are given certain names. Show Table 1 or a portion of it. Have the students name their different size sediment particles.

2. Explain that the strength of a current (velocity and viscosity) determines the size (and therefore weight) of particle it can carry. Relate this idea to common examples--heavy paperweight holds down papers in a strong wind hose nozzle must be turned to narrow spray to wash large particles off a car or sidewalk why large food particles are left in a draining kitchen sink or sand left in a draining bathtub, etc. Children can demonstrate how the particle size depends upon the strength of the current by blowing gently and then blowing harder on the sediment mixture and observing the size of particles that are moved. Discuss the sizes of particles a river during a spring flood might carry compared to a small creek during a dry fall. Discuss sediment sizes found on beaches and other environments with which the children are familiar. Show pictures of sediments in various environments. Define detrital sedimentary rocks as those composed of transported particles, as opposed to chemical sedimentary rocks which are made up of chemical precipitates such as rock salt, rock gypsum, and cave limestone. Pass around detrital sedimentary rocks and discuss in what environment they may have been deposited. Name the sedimentary rocks (conglomerate, sandstone, shale, etc.)

Expansion. Provide each group with a container of sediment from a different place or sedimentary environment. The sediment should be loose and dry. It may have been collected by the class on a field trip or brought in by students from their own backyards or from places they have visited (the beach, a sandbar of a river, a lake shore, a hillside, a stream bed, glacial deposit, etc.). Have each group sieve and measure the different sized particles. What conclusions can be drawn from the results? High energy environments with fast currents such as ocean beaches with big waves and raging rivers will usually have coarser sediments.

Lesson Evaluation:

1. Give students a new mixture to separate using sieves such as mixed wild bird seed or a snack mix of crackers, nuts, M&Ms, sesame seeds, and seasonings.
2. Have students answer questions like these:
    a. What type of sediment would you expect to find at the bottom of a quiet lake?
    b. What is the common term for boulders, cobbles, pebbles, and granules?
3. Give students rock specimens and have them identify the particle sizes (gravel, sand, mud) in them or name the rock (conglomerate, sandstone, shale, etc.)
4. Have students identify environments in which rock samples may have formed (dessert or beach sand dune, landslide deposit, ocean bottom sediment, etc.).

Reference

National Science Teachers Association. (1990). *Science teachers speak out: The NSTA lead paper on science and technology education for the 21st century.* Washington, DC: Author.

SSMILES

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Thinking Small: Milligrams, Micrograms, and Counting Atoms

Grades 6-9

Mathematics Skills/Concepts:

common fractions, decimals, exponential notation, orders of magnitude, area, volume

Science Concepts/Processes:

International System of Units (SI), measurement, density, atomic mass, counting atoms

Prerequisite Skills:

Students should be familiar with the International System of Units (SI) and the atomic nature of matter.

Objectives:

The student will be able to:

1. use several SI prefixes that represent fractions of the base unit,
2. prepare pieces of aluminum foil having mass from one gram to one microgram ($1\mu g = 10^{-6}g$),
3. determine the thickness of aluminum foil using the density concept,
4. make calculations with numbers expressed in exponential notation, and
5. represent as an order of magnitude the number of atoms in several pieces of aluminum foil.

Rationale:

Measurement activities offer many opportunities to integrate science and mathematics. Although measurement usually involves objects of hands-on size, quantities whose magnitudes are near the limits of our direct perception often occur in science, mathematics, and daily life. Nutritional data on foods and vitamins, for example, are often given in milligrams. By law, foods cannot be sold if some substances are present in concentrations as low as one part per million (ppm).

Beginning with a one gram square of aluminum foil, pieces can be cut such that each subsequent piece is reduced by an order of magnitude. With care, a one microgram piece of foil can be prepared. The thickness of the foil can be determined indirectly using the density of aluminum. Finally, the small size of atoms can be illustrated by calculating the very large number of atoms in a microgram piece of foil.

The following SI prefixes are used in these activities.

PREFIX	SYMBOL	EXPONENT	FRACTION	DECIMAL
deci-	d	10^{-1}	1/10	0.1
centi-	c	10^{-2}	1/100	0.01
milli-	m	10^{-3}	1/1000	0.001
micro-	µ	10^{-6}	1/1000000	0.000001

These activities could be used to supplement lessons on length and mass measurement at the upper elementary and middle school level. They could also be part of a unit on atoms or a unit on orders of magnitude. In addition, these activities provide a concrete illustration of exponential scales such as the Richter scale (earthquake magnitudes) and the pH scale (acidity).

The National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989) recommends that the curriculum in the elementary and middle school should include extensive concrete experiences using measurement and should develop concepts related to units of measurement. The National Science Teachers Association (NSTA) position statement *Use of the Metric System (1985)* recommends that the International System of Units (SI) and its language be incorporated as an integral part of the education of children at all levels.

Lesson Outline:

Time: two 45-minute lessons should be sufficient for these activities

Materials/Supplies:

- pre-cut square of household aluminum foil weighing about one gram
- centimeter ruler
- pair of scissors
- single edge razor blade (or X-acto knife) with a piece of adhesive tape over the cutting edge for safety
- piece of hard cardboard as a base for cutting with the razor blade
- paste or clear tape for mounting pieces of foil on the worksheet
- calculator

Optional equipment:

- mass balances sensitive to ±0.1 g
- standard metric masses (1 g to 1 kg)
- magnifying glasses

Preparation:

1. *Introduction.* Hold up one of the pre-cut square pieces of aluminum foil and ask your students to estimate whether its mass is closer to ten grams, one gram, one decigram, one centigram, or one milligram. Then distribute a pre-cut square of foil to each pair of students. Have them measure the edge using centimeter rulers and record the measurement on the worksheet. If mass balances sensitive to 0.1 g are available, have them weigh their foil square and record the mass. There will be some variation; however, the values should be approximately one gram. If balances are not available, simply mention that the squares weigh one gram.

2. Decigrams (dg), centigrams(cg), milligrams(mg). Ask your students how a decigram (10^{-1}g) piece of aluminum foil could be made from the 15 X 15 cm square. One way is to cut a 1.5 cm wide strip from one edge of the square using a ruler and pair of scissors. Then another order of magnitude reduction is made by cutting off a square (1.5 cm on edge) from one end of the decigram strip. This square will weigh a centigram (10^{-2}g). Then a milligram (10^{-3}g) is made by cutting a 0.15 cm strip from the centigram square. These three foil pieces can be mounted on Page 2 of the worksheet with paste or clear tape. If you have standard metric masses (1 g to 1 kg), objects whose masses range from 1000 g to 0.001 g (seven orders of magnitude) can be arranged in sequence. Ask your students how many of the lightest (1 mg) pieces of foil would equal the one kilogram mass? (Answer: one million)

3. Micrograms (μg). The milligram piece of foil can be reduced further. A razor blade, good eyes, and some care are needed. A magnifying glass may also be useful. (If any of your students are planning to become neurosurgeons, this might be an especially good activity.) Have students cut another 0.15 cm X 1.5 cm strip of foil and, by three further order of magnitude cuts on this milligram piece, produce a tiny square of foil weighing approximately one microgram. Since pieces whose dimensions are less than one millimeter are difficult to measure with a ruler, students need to estimate where to cut. These smaller pieces of foil can be mounted on Page 2 of the worksheet. For cutting the very tiny pieces, a hard cutting base is useful to prevent the pieces from being embedded in the base. Clear tape is handy for transporting and attaching the smaller pieces to the worksheet. When all of the pieces of foil are mounted, have students write under each piece on the worksheet the mass in grams as a common fraction and a decimal number.

Trace amounts of substances are sometimes reported in parts per million (ppm). One microgram in a gram (10^{-6}g : 10^{0}g) or one milligram in a kilogram (10^{-3}g : 10^{3}g) is one part per million. Some analytical techniques are capable of detecting substances at the parts per billion (ppb) level. In February 1990, millions of bottles of Perrier sparkling water were recalled from world markets when benzene levels were found by chemical analysis at 13-15 ppb, several times the Environmental Protection Agency limit of 5 ppb. One part per billion is one microgram in a kilogram (10^{-6}g : 10^{3}g). When discussing parts per million and parts per billion it is useful to remind students that the familiar percent (%) is parts per hundred.

$$(\text{part/total}) \times 10^{2} = \text{parts per hundred } (\%)$$
$$(\text{part/total}) \times 10^{6} = \text{parts per million (ppm)}$$
$$(\text{part/total}) \times 10^{9} = \text{parts per billion (ppb)}$$

4. Thickness of foil. If you ask your students to measure the thickness of the aluminum foil, they probably will reply that it is too thin to be measured with their rulers. The thickness, however, can be determined indirectly from the density of aluminum.

$$D = \text{mass} / \text{volume}$$
$$D = 2.7\ \text{g/cm}^3 \text{(for aluminum)}$$

Consider again the original one gram square of foil 15 cm on edge. Its mass, M, is 1.0 g. Its volume is,

$$\begin{aligned} V &= M/D \\ &= (1.0\ \text{g}) / (2.7\ \text{g/cm}^3) \\ &= 0.37\ \text{cm}^3 \end{aligned}$$

A rectangular piece of foil approximates a rectangular solid, and the volume of a rectangular solid is the product of the three mutually perpendicular dimensions. For a square piece of foil, one of these dimensions is the thickness, t. The volume of the original foil square is,

$$V = (15\ \text{cm})\ (15\ \text{cm})\ (t\ \text{cm})$$

Setting this expression equal to 0.37 cm³ and solving for thickness, t, gives a value of 1.6×10^{-3} cm. This can also be expressed as 16 micrometers ($1\mu m = 10^{-6}$m). A micrometer is also called a micron. Students should carry out these calculations on a calculator.

(NOTE: Aluminum is a relatively reactive metal chemically, and when exposed to the air, it forms a surface coating of aluminum oxide which adheres tightly to the underlying metal, protecting it from further reaction. This is why aluminum does not corrode as readily as iron, a less reactive metal whose oxide (rust) easily flakes away exposing underlying iron to further corrosion. In calculating the foil thickness, are we justified in neglecting the aluminum oxide coat, whose density is different from aluminum? The answer is yes. Aluminum foil is thousands of atoms thick so the coating of aluminum oxide has a negligible effect on foil thickness.)

5. Counting atoms. Atoms are very small, and one way to illustrate this is to consider how many aluminum atoms are in the tiny microgram piece of foil. First ask your students to make an estimation. Is the number of atoms in a microgram piece of aluminum foil closer to:

a. the population of New York City (about 7.4 million or 7.4 $X10^6$),

b. the population of the United States (about 250 million or 2.5 $X10^8$), or

c. the population of the Earth (abut 5.4 billion or 5.4 $X10^9$)?

The details of how the number of atoms are calculated are most appropriate in a chemistry class. The results, however, can be of interest in other classes. The calculation involves several chemical concepts--the atomic mass scale, the mole, and Avogadro's number.

The original atomic mass scale was set up based on the lightest atom, hydrogen. Although the present atomic mass scale is no longer based on hydrogen, a normal hydrogen atom has a mass very close to one atomic mass unit (amu) on the present scale. Aluminum atoms are 27 times heavier than hydrogen atoms, so the atomic mass of aluminum is 27 atomic mass units (amu).

An amount of an element whose mass in grams is numerically equal to its atomic mass (amu) is a mole (mol) of that element. For hydrogen, 1.0 gram is one mole; for aluminum, 27 grams is one mole.

Since the mass ratio of an aluminum atom to a hydrogen atom is 27:1, any amounts of these elements having this mass ratio contain the same number of atoms, i.e., a 1:1 atom ratio. A pound of hydrogen, for example, contains the same number of atoms as (2 X27) milligrams of aluminum. In each example, the aluminum : hydrogen mass ratio is 27:1, so the number of atoms is the same. If students find these atomic ideas a bit abstract, a more concrete example might help. A golf ball is about 18 times heavier than a ping-pong ball, an 18:1 mass ratio. A pound of ping-pong balls, therefore, contains the same number of balls as 18 pounds of golf balls. Or any other amounts of golf balls and ping-pong balls that have an 18:1 mass ratio have the same number of balls, a 1:1 ball ratio.

The number of atoms in one gram of hydrogen (1 mol) is the same as the number of atoms in 27 grams of aluminum (1 mol). This number is Avogadro's number; it is the number of atoms in one mole of any element. Avogadro's number has been experimentally determined quite accurately, although for the calculations here, 6.0 X 10^{23} atoms per mole is sufficient.

The number of atoms in a one microgram piece of aluminum foil can be worked out with a calculator as follows:

(piece of foil) (atomic mass of aluminum) (number of atoms in any element) =
(1.0 $X10^{-6}$ g) (1 mol/27 g) (6.0 $X10^{23}$ atoms/mol) =

2.2 $X10^{16}$ atoms

This number is much larger than the population of the Earth. If the atoms in a microgram piece of aluminum foil were equally distributed among all the people on the Earth, how many atoms would each person get? Again, a calculator is a must.

(2.2 $X10^{16}$ atoms) / (5.4 $X10^9$ people) = 4.1 $X10^6$ atoms/person

Over four million atoms for each person on Earth in a piece of foil that is barely visible.

In general, order of magnitude means a quantity to the nearest power of ten. As an order of magnitude, the microgram piece of foil contains 10^{16} atoms. This is written below the 1 µg piece of foil at the bottom of Page 2 in the worksheet. Now have your students determine and write the number of atoms (order of magnitude) below the other pieces of foil at the bottom of their worksheets.

Evaluation:

Students can be evaluated on their ability to measure accurately and estimate reasonably. They can also be evaluated on their ability to express values in exponential notation, common fractions, decimal numbers, and as an order of magnitude.

References

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Science Teachers Association. (1985). *Use of the metric system.*

WORKSHEET - THINKING SMALL

1. You will be given a square piece of aluminum foil whose mass is about one gram. With your centimeter ruler measure one edge of the square and, if you have a balance sensitive to 0.1 g, weigh it. Record your results below:

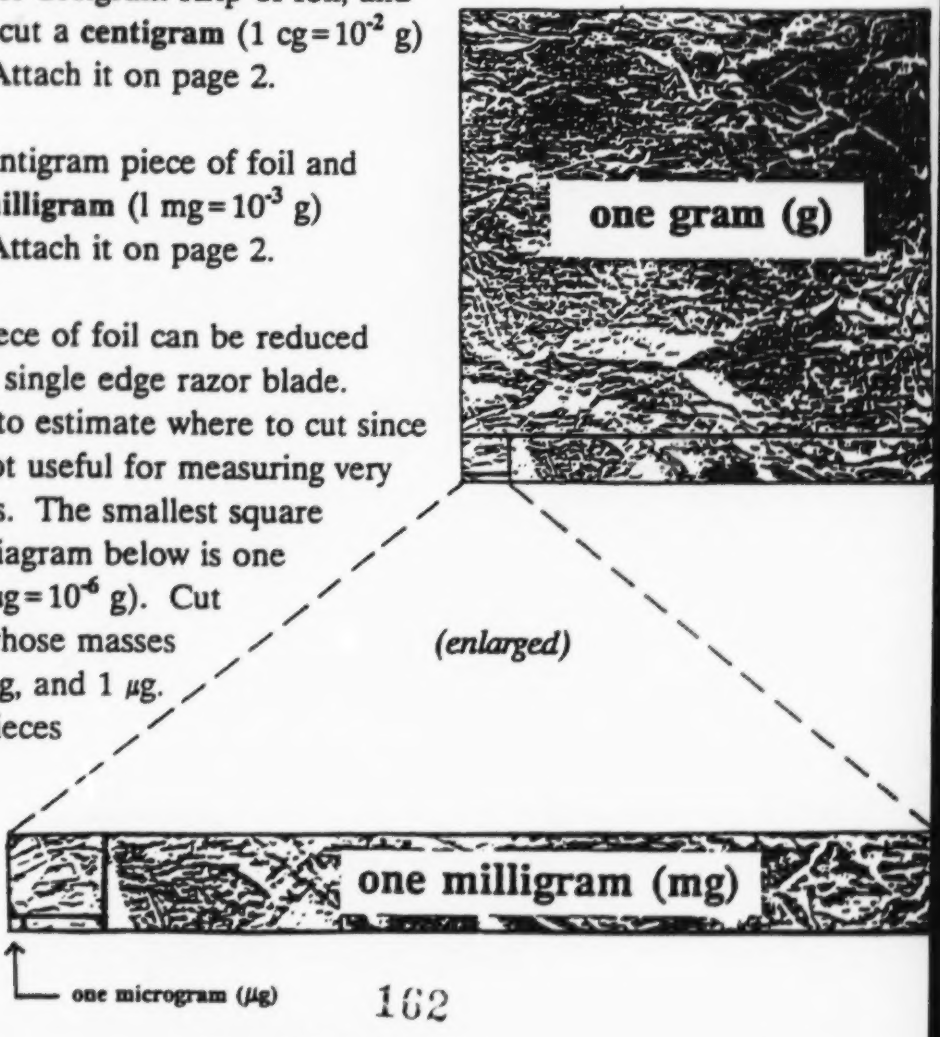
   edge of square __________ cm mass of square __________ g

2. Using your centimeter ruler and scissors, measure and cut a piece of foil whose mass is one **decigram** (1 dg$=10^{-1}$ g). Attach this piece on page 2.

3. Now cut another decigram strip of foil, and from this strip cut a **centigram** (1 cg$=10^{-2}$ g) piece of foil. Attach it on page 2.

4. Cut another centigram piece of foil and from it cut a **milligram** (1 mg$=10^{-3}$ g) piece of foil. Attach it on page 2.

5. A milligram piece of foil can be reduced further using a single edge razor blade. You will need to estimate where to cut since your ruler is not useful for measuring very tiny dimensions. The smallest square shown in the diagram below is one **microgram** (1 μg$=10^{-6}$ g). Cut pieces of foil whose masses are 10^{-4} g, 10^{-5} g, and 1 μg. Attach these pieces on page 2.



Mount your one decigram piece of foil over this sentence.

Mount the six pieces of aluminum foil on this page. Then determine the mass (grams) of each piece as a common fraction and as a decimal number. Finally, determine the number of aluminum atoms in each piece as an order of magnitude. A microgram piece of aluminum foil contains about 10^{16} atoms.

	decigram **10^{-1} g**	**centigram** **10^{-2} g**	**milligram** **10^{-3} g**	**10^{-4} g**	**10^{-5} g**	**microgram** **10^{-6} g**
common fraction						
decimal number						
atoms (order of magnitude)						10^{16}

SSMILES

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Investigating the Uses of Numbers in Science and Everyday Life

Grades 3-6

Mathematics Skills/Concepts:

identifying and classifying types of numbers (ordinal, cardinal, nominal, denominal, coordinate, percents, and fractions), making and interpreting bar graphs, graphing ordered pairs of data, measuring length and weight, making quantitative observations

Science Skills/Concepts:

observing and naming properties of natural objects, describing and communicating data, collecting and recording data, organizing and interpreting data

Objectives:

By conducting hands-on activities, the students will be able to:

1. develop an appreciation for the importance and use of numbers in science and everyday life,
2. classify numbers by their use,
3. describe six different purposes or uses of numbers in science and everyday life,
4. use numbers in many different ways in conducting a scientific investigation, and
5. describe the behaviors and preferences of land snails.

Rationale:

Numbers are all around us; where would we be without them? Certainly numbers are important in our everyday life. Who doesn't wonder, "What time is it?" upon awakening. How often do you count how many items you have or how many times you've done something? Does your age, weight, clothing size, or the number of calories you've consumed cross your mind? How about the amount of money you have? Do you think, "What do I need to do first?" or "What address, floor, or room number do I need to go to?" Have you called anyone on the phone, sent a letter, written down your social security number, or used a credit card lately? All of these activities involve numbers. See Figure 1 for examples of how numbers can be grouped and classified by their use or purpose.

This lesson combines mathematics and science by making the student aware of the many different roles numbers play in our everyday lives and then applying these same uses of numbers to conducting a scientific investigation. Observation is a key skill that not just scientists but everyone needs. To be able to accurately communicate what has been observed is vital to getting along in our world. Since observations are both quantitative and qualitative, we need to be able to use numbers to describe our experiences and observations. This exercise provides practice in recognizing and classifying numbers according to how they are used in everyday life situations and then applies these same uses of numbers to a scientific investigation. The student will then realize the important roles numbers play in everyday life and how numbers perform these same roles in science.

Science and mathematics are intimately related. Scientific investigations could not be conducted without making measurements, observing sequences of events, counting specimens or events, noting precise locations, and identifying and comparing data. This lesson will make the student aware of how important numbers are to science and give the student practice in collecting, recording, and analyzing scientific data. The National Science Teachers Association (1990) recommends that science be integrated with mathematics so that children will learn the connections between the two disciplines and will learn to apply them in an integrated way to their everyday life. This lesson helps students build a connection between using numbers in many ways in everyday life and in these same ways in science.

In *Curriculum and Evaluation Standards for School Mathematics* (1989), the National Council of Teachers of Mathematics (1989) recommends, among other items, that students be provided opportunities:

1. to make connections between mathematics and their daily lives and to value the role of mathematics in our culture and society;

2. to interpret the multiple uses of numbers encountered in the real world and to relate everyday language to mathematical language;

3. to collect, organize, and describe data; to make and use measurements in problem and everyday situations; to understand the attributes of length, weight, area, volume, time, temperature, and angle; and

4. to apply mathematical thinking and modeling to solve problems that arise in other disciplines such as science.

The following lesson will allow students to practice skills in all of these important areas.

Lesson Outline:

Time: two 45-minute periods--the exploration and invention phases should be completed the first day; the expansion phase can be done the next day.

Student Work Group: Most of this lesson can best be carried out by dividing the class into small cooperative learning groups.

Materials for the Exploration Phase:

various printed items with numerals printed on them for the sorting activity
laminated box tops
food labels
newspaper clippings
dot-to-dot and color-by-number worksheets
magazine ads
graphs
used envelopes
diagrams
photocopied clippings out of scientific reports and science texts
assembly directions, recipes, etc.

(More suggestions for what to use for each category are listed in Figure 1.)

Materials for the Expansion Phase:

land snails and containers (see Figure 2)
a sheet of white office paper for each student
several sheets of fine-grained sandpaper
eyedroppers
small container of table salt
dishwashing liquid
pure water
hot water
ice cubes
metric rulers
clock with second hand
scale or balance
aluminum foil
graph paper
paper and pencil for recording data.

Procedure:

Exploration

Start out with the class as a whole. Ask students to think about how many numbers are used in everyday life. Do all numbers tell how many? Can anyone name an example of a number that does not tell how many? Perhaps a student will think of a social security number or first prize or street address. Ask students to name examples of numerals visible in the room or examples that they can remember. List these on the board and discuss the purpose or use of the number--what is the number telling us--how many? in what order? where? how heavy? Students may point out the numerals on a clock or calendar. What purpose do the numbers serve? They allow us to measure time. We could say that these numbers are used for measurement. Perhaps there are student papers posted in the room with 100% or 95% marked on them. What is the purpose of stating the number as a percent? For comparing part (the correct part) to the whole (the whole assignment). So the purpose of a percent is comparison. Maybe there's a map on the wall with latitude and longitude lines marked on it. These latitude and longitude numbers help us locate places on the map and so their function is location. Are there fire drill or homework assignment directions posted somewhere in the room with steps listed below? The numbered steps are indicating sequence--what to do first, then second, etc. Many pieces of school equipment will have serial numbers marked on them for identification. Continue with examples until you are sure that the students have grasped the idea of classifying numbers by their function or use. But don't show them Figure 1 or list all the categories on the board. The main point of the exploration phase is for the student to think of his or her own classification system by herself or himself. Only by devising and testing their own systems will the students truly understand what is involved in the classification of numbers by function or purpose.

Divide the students into small groups. Assign each student a different role and later have them switch roles so that everyone gets a turn doing each task--chooser of the item to be classified, classifier, recorder/documenter, mediator. Pass out the laminated food labels, box tops, and clippings for them to classify. Be sure that there are some examples of each category given to teach group. See Figure 1 for ideas and examples. Have students label their groupings with the use or function of the numbers written on a slip of paper (examples: location, identification, count, measurement, etc.).

Figure 1. *Categories and examples of number uses.*

Categories	Examples
Count (how many) = Cardinal Number	number of sticks in gum package, number of puzzle pieces on box lid, number of players on video game, video game scores, number of items or servings in a package
Sequence (order of events or items)	numbers on dot-to-dot picture; page numbers in a book; directions for assembling a toy; playing a game; 1st, 2nd, 3rd place ribbons for a race; 1st, 2nd, 3rd prizes awarded in contest ad;steps in a recipe from a cookbook, shoe size
Location (where)	room number in school building, map coordinates,numbers on crossword puzzle square, graph coordinates, numbers on paint by number, street address, zip code, P.O. box on old envelopes,phone number (may also be placed under identification.)
Identification and Code = Nominal Number	lock combination, serial numbers, student ID number, UPC bar codes, social security number, CB radio codes, airline luggage tags, flight numbers, credit card numbers,driver's license number, license plates, raffle tickets
Comparison (shows relative amount)	grades on school papers, advertised sale items, 2% milk, other dairy product labels with fat %, percentages, fractions, ratios, scale model train ratios
Measurement = Denominal Number	
Money Measurement	price marked on comic books or magazines in dollars and cents, movie theater and concert admission prices
Weight Measurement	net weight marked on candy bars in ounces and grams, student's weight on scales, weights on barbells in lbs and kg
Volume Measurement	fluid ounces of soda in can; cups, tsp, ml in recipes;cubic yards or meters of top soil in yellow pages ad
Length and Area Measurement	student's height in feet and inches, meters, cm;bullet size in mm, room size in sq ft, yards of fabric, acres of land for sale, sq yd of carpet
Temperature Measurement	outside temp in degrees Fahrenheit and Celsius, cooking temp
Speed Measurement	33 or 45 rpm records, speed limit signs in mph or kph
Time Measurement	time on clocks, dates on calenders, times of TV shows
Angle Measurement	degrees marked on protractors, diagrams in mathematics books
Energy Measurement	kilocalories, calories on food labels; BTUs on furnaces

Figure 2. *Land snail care and facts.*

Collection

Snails prefer a wet, dark environment. Look under flat rocks, rotting logs, and among leaf litter. Snails are usually active and easier to find after a rain or buy snails at a pet store or from a biological supply company.

Housing

The best housing will meet the following specifications: (a) transparent so that snails can be observed, (b) maintains high humidity so that snails will not dry out and estivate, (c) a covered enclosure so that snails will not escape, (d) large enough so that snails will have room to move about, (e) furnished with a few centimeters of soil, a few twigs, leaves, etc. so that snails will have places to hide, burrow, or lay eggs, and (f) a shallow source of fresh water. A small aquarium or clear plastic shoe box with screen cover, a fish bowl covered with netting, and a very large jar with holes punched in the lid would all make suitable homes for snails.

Food

Land snails are generally herbivores and will thrive on a variety of plant foods. Try lettuce, ivy, geranium leaves, celery, carrots, apple, and lichens.

Reproduction

Most land snails are hermaphroditic (possessing both male and female reproductive organs). When two land snails mate, each receives sperm from the other and then produces fertilized eggs. Eggs are laid in a hidden place where they will stay moist until hatching into tiny snails.

Aestivation

Land snails need moisture to survive. During dry periods, land snails withdraw into their shells and seal the opening with mucous to protect themselves against desiccation.

Scientific Classification

Snails belong to the class Gastropoda, in the phylum Mollusca. Land snails have lungs and are in the subclass Pulmonata. The common garden snail, Helix, is also known as escargot and is eaten by many people as a great delicacy.

Foot - a large muscular organ used for locomotion. Continuous waves of muscle contractions allow the animal to move forward. Land snails secrete a sticky slime which helps the snail move and protects its delicate foot from abrasion. The snail's enemies, beetles and ants, are sometimes trapped in the slime while the snail escapes.

Head region - the part of the snail's soft body that has one or two pairs of tentacles, eyes, and mouth with jaws, lips, and rasping tongue. Eyes may be located at the end of the tentacles.

Radula - a broad, short, toothed tongue for stripping off pieces of vegetation.

Invention

1. Have groups report their categories of classification. Write these on the board and list examples under each group. Discuss disputed examples and categories.

2. Ask students to name ways scientists might use numbers. Some examples are: (a) biologists measure insect wingspans, count black footed ferret populations, map locations of colonies of killer bees moving north, and record whale songs to analyze sequences of different melodies; (b) geologists calculate the tons of rock blown out of a volcano, the parts per billion of pollutants in stream water, and label fossil dinosaur bones for identification; (c) foresters count tree rings and number of hardwood trees per acre; and (d) engineers estimate the deflection of balcony support beams and the maximum amount of weight a bridge can support.

3. Discuss which of the sorted items were science related. Which of the measurements were determined by scientists? Discuss how important numbers are in science.

4. Present the students with the following scenario to illustrate the importance of numbers in communication:

> You have a new satellite unscrambler for your TV but it's not working well--it seems to omit all the numbers. Here are some examples of the audio parts of a few TV shows. Can you make sense of them?
>
> (TV Game Show) "OK, folks, she's got _ seconds left in our _ round. Spin the dial. Let's see now, for _ dollars, tell me how many floors the Empire State Building has. __..."
>
> (News Report) "There has been a __ car accident on Highway __. __ people were injured. Take Route __ to bypass the accident area. . . ."

(Police Adventure Show) "__ - __ car __, there is a __ in progress on the _ block of _ Street. Proceed to apartment where __ suspects are holding __ hostages. . . ."

(Comedy Show) "A __ year old kid came home with a on his paper and his mother asked him to tell her what the other kids got on their papers. He said __, __, __, and __. So his mother asked how come his paper was __. . . ."

(Soap Opera) "Oh, Violet, you're the ___ person I expected to visit me in the hospital, not the __. How is your _ husband and the _ children? You know, they are giving me __ years to live now. . . ."

Point out how the dialogue loses meaning when the numbers are omitted. Students can put different numbers in the blanks and see how the meaning changes. Students can suggest other instances in which it is necessary to use numbers to communicate well.

5. As a closure, the teacher should point out to the class the six major purposes of numbers - to indicate: (a) how many or the count, (b) sequence or ranking, (c) location, (d) identification or symbolic code, (e) comparison, and (f) measurement.

Expansion

Explain to the students that now they will use numbers in many different ways in conducting a small scientific investigation. Pass out a container of land snails to each group. It would be best if there were enough for each pair of students to have a snail. Remind students that snails are wonderful, fascinating living animals worthy of respect and humane treatment. Snails are important ecologically as a food source for birds, fish, crayfish, lobsters, and other animals. Unfortunately, some fresh-water snails are hosts for parasites that are dangerous to people; however, the common garden snail is eaten as a delicacy for many people, as also are many different types of sea snails such as abalone, periwinkles, and top shells. Sea snail shells are used for making pearly buttons, jewelry, cameos, and fabric dyes. More information about snails is available in Figure 2 and should be shared with students.

Students of each pair should divide the following roles--equipment procurement and set-up, predictor, observer/measurer, recorder/documenter, clean-up. Have students switch roles periodically so that each student gets a turn at each task. Have each group of students perform activities 1 through 6 and some others of the following:

1. Assign an identification number to the snail (this might consist of the student's initials plus a number).
2. Record the date and time of the observations.
3. Record the place from which the snail was collected
4. Count the number of whorls on the snail's shell.

Ask student groups to predict and record their predictions of all of the following before actually performing the activities:

5. Measure the maximum diameter of the snail's shell in mm.
6. Weigh the snail.
7. Describe and sketch the snail; color, markings; label shell, foot, head, tentacles, eyes, mouth, etc.
8. Carefully place the snail on a piece of paper. Record the speed at which the snail moves (time the snail for one or two minutes and measure the distance traveled: speed = mm/minute).
9. Now wet the piece of paper. Does the snail travel faster? Record the speed. Try a piece of fine-grained sandpaper. Does the snail move faster on a smooth or rough surface?
10. Place the snail in the middle of a piece of wet paper. Put a few drops of hot water (about 50° C) a few centimeters away from the snail on one side and a small ice cube a few centimeters away on the other side. Which way does the snail move?
11. Try putting a drop of diluted dishwashing liquid (half water, half detergent) on the wet paper about 2 cm away from the snail. Does the snail move toward or away from the detergent? (Snails will avoid the irritating detergent.)
12. Try a few grains of salt on the wet paper. How does the snail react to these? (Snails will avoid the desiccating and irritating salty water.)
13. Allow the snail to move through a puddle of clean water to wash off and then put the snail back into the aquarium. Darken one side of the aquarium by covering it with aluminum foil. Do the snails prefer the light or dark side of the aquarium?
14. Put various foods into the aquarium and observe which food the snails prefer. Count the number of snails feeding on each type of food. Weigh each piece of food before and after the snails have dined. How much was consumed of each food?
15. Make a sketch map of the aquarium and plot the snail's travels on your map. Mark an X and a sequence number at places the snail stops and does something. Record what the snail does. Can the snail travel upside-down? Draw a reference grid on your map. Record beginning and ending positions. Record the length of time the snail was observed--beginning and ending times.
16. Observe the snails at various times of the day. Record the time, lighting conditions, and snail activity.

Individual pairs of students should now get together with other group members to pool data and discuss results. Students should divide the following roles among themselves--observation and data reporter, graph maker, trend finder, final report recorder. Students should perform the following tasks:

1. Rank snails from fastest to slowest on dry paper, then wet paper. Was the same snail the fastest both times?
2. Graph the number of whorls vs. maximum diameter. What conclusion can you draw from this?
3. Discuss the snail preferences: smooth vs. rough, warm vs. cool, light vs. dark, food preferences, etc. What fractional part of the total snail population behaved in these ways? What conclusions can you make? Students may want to make bar graphs of some of these and display these products.
4. Have students name an example of numbers used in the

following ways during the experiment (assign one or more tasks to each student): (a) a cardinal number indicating how many (number of whorls in shell, number of snails on dark side of aquarium, etc.); (b) a nominal number used for identification (identification number); (c) a denominal number used for measurement (maximum diameter, weight, distance traveled, speed, date, time, etc.); (d) a number used to indicate location (beginning and ending map coordinates, numbers marked on sketch maps to indicate position of observed snail behaviors); (e) a number used to indicate comparison (fraction or percentage of snails that preferred certain foods, fled from salt, detergent, etc.)

If no snails are available, other small animals such as slugs, beetles, crickets or earthworms can be substituted with modifications.

Evaluation:

1. Using data from Figure 1 or made-up data, list the six categories on one side of the paper and mixed-up examples on the other side. Have the student match the examples with the correct classification category.

2. Show students a diagram of a snail and have them use numbers to describe the parts of the snail. (For example, students might write that it has 2 eyes and 1 foot, that the shell measures approximately x mm in diameter, that 100% of the soft body can fit inside the shell, and mark an X with a number on it at the places where the radula and tentacles are located.)

3. Tell students to imagine that they are going to conduct a scientific study of an endangered species of bird. Have students suggest an example of how numbers might be used in the following ways during this study: (a) a cardinal number used for counting (example: number of eggs laid or birds per acre); (b) an ordinal number used to tell sequence (example: sequence of mating dance and courtship behavior); (c) a number used to indicate location (example: map coordinates of nesting sites); (c) a nominal number used for identification (example: numbers on bird leg bands); (d) a number used to show comparison (example: percentage of eggs hatching and surviving to maturity); (e) a denominal number used for measurement (example: grams of insects consumed per day per bird).

References

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